

# **Adopting the Commissioning Process for the Successful Procurement of Schools**

*Receiving Value for the Community's Investment*



**January 16, 2003**

**Prepared By:**



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## Forward

This Guide has been developed by the Department of General Services – Division of the State Architect and is intended to be used by school districts, programmers, design professionals, contractors, operations and maintenance personnel, and Commissioning Authorities to understand the Commissioning Process and their role in it. ASHRAE Guideline 0 should be referenced for additional details.

## Introduction

The Commissioning Process is an Owner's means of achieving a successful project through the application of tools developed in the practice of quality in manufacturing and process construction, which has been refined for the planning, design, construction, turnover, and operation of facilities.

The goal of the Commissioning Process is to:

- Reduce cost of constructed projects
- Improve quality through better matching of needs to the delivered project
- Reduce life cycle cost
- Delivery new buildings, rehab existing buildings, modify spaces in buildings and additions to school facilities that result in zero to a very low number of problems at turnover
- Provide extremely effective systems manual and training
- Develop an effective quality team (the commissioning team) for every project

This Commissioning Process Guideline is intended to provide all stakeholders involved with the procurement of facilities an understanding of what is required to achieve a successful facility. This includes school district superintendents, administrators, financial officers, board members, facility managers, operation and maintenance personnel, principals, and others, such as their planning, design, and construction professionals.. As the activities detailed in this Commissioning Process Guideline are best practice, it is likely that some of the activities are already being implemented by many school districts.

To accomplish this intent, the information in this Guideline provides implementation details of the Commissioning Process that has been summarized in the Collaborative for High Performing Schools<sup>1</sup> (CHPS) *Best Practices Manual* (CHPS 2002) under the Commissioning Process section. As this Commissioning Process Guideline is more comprehensive than that in the CHPS Manual and is based on the latest knowledge of industry (ASHRAE 2002), most of the information in the CHPS Manual should be replaced by this Commissioning Process Guideline.

In order to understand the Commissioning Process, one must first understand the context in which facilities are procured and what the responsibilities of the Owner are to achieve a successful facility. Then, the detailed activities of the Commissioning Process can be defined for the pre-design or planning, design, construction, turnover, and occupancy and operation phases of a typical project.

## Who is the Owner of a School?

Throughout this Commissioning Process Guideline the Owner is referenced. Therefore, it is important to understand who the "Owner" is. Traditionally, the Owner is the contractual contact for the architect, engineers, and contractors. This could have been a facility manager, contracting officer, principal, or similar individual. However, when viewing the procurement process from a larger perspective, the Owner is actually composed of many individual entities, with the general community providing the funding for the project. Therefore, while there will still be a single contractual owner point of contact for school projects, the term Owner in this Guideline includes:

- Contractual contact
- Technical contractual contact
- Superintendent
- School board

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<sup>1</sup> A summary of the CHPS program is contained in *Appendix A: CHPS Program Summary*.

- Financial officer
- Principal
- Vice principal
- Administrative personnel
- Facility manager
- Operation and maintenance personnel
- Teachers
- Students
- Parents
- Community organizations
- Neighbors

## ***An Owner's Responsibility***

To achieve a successful school requires that the Owner implement a quality-based process for the procurement of the school. There are responsibilities that must be accomplished by the Owner that cannot be abdicated to an architect, engineer, or contractor – primarily due to the fact that the Owner must continually evaluate the architect's, engineer's, and contractor's processes to verify the Owner's end goals are being achieved.

In general, the key responsibilities of the Owner are:

- Clearly define, document, and convey success criteria
- Review how design professionals achieve success criteria
- Provide Owner input for construction documents
- Continually verify construction achieves success criteria
- Verify operations and maintenance personnel are trained and have adequate documentation
- Continuous evaluation and improvement of procurement process

All of these responsibilities can be achieved through the adoption of the Commissioning Process as the school district's means of implementing quality during procurement of their facilities. As these responsibilities are new to many school districts, the use of a qualified Commissioning Authority firm with sufficient depth and breadth of experience is often required to train internal personnel to take on the responsibilities for managing and leading the Commissioning Process.

The leadership (the Commissioning Authority) for the Commissioning Process can be either school staff (properly experienced with the Commissioning Process), a third party Commissioning Authority firm, or a combination of school staff and a third party.

## ***What is a Quality Process?***

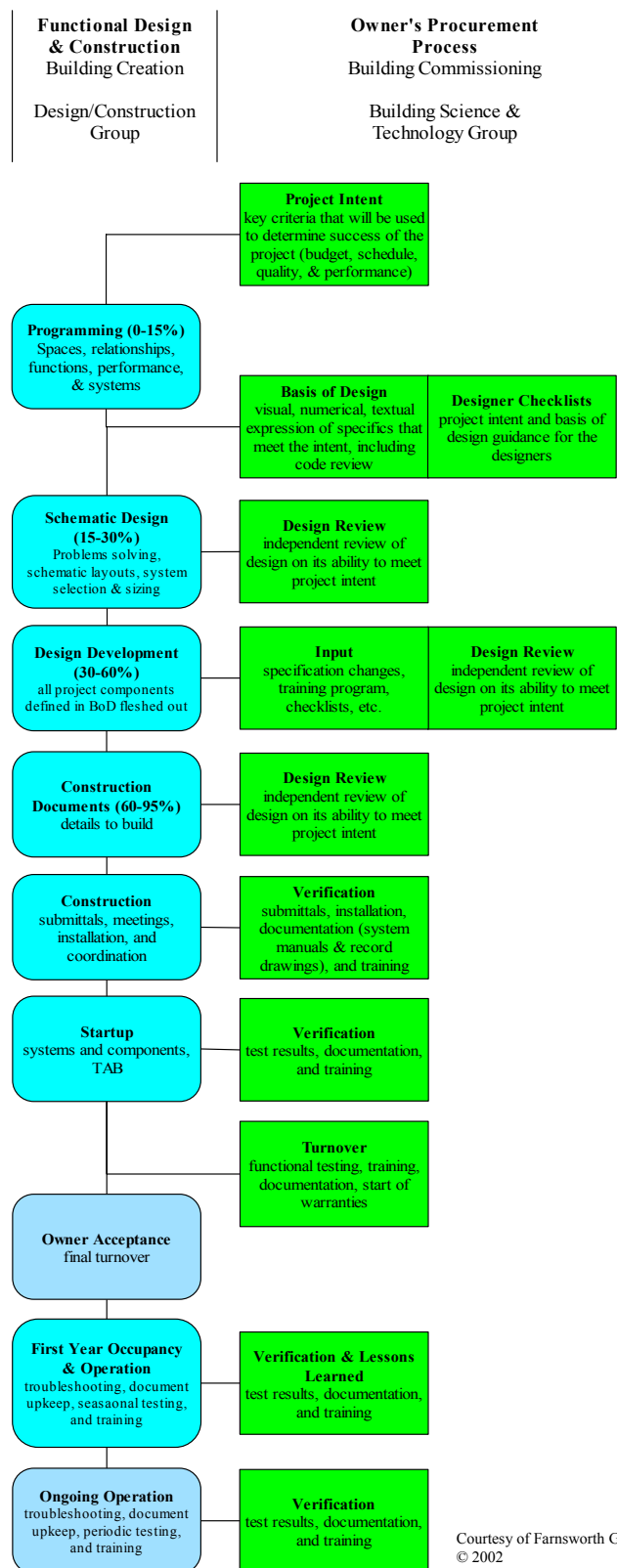
There are several key tenets that define a quality process. It is important to understand these tenets, to reduce confusion when adopting the Commissioning Process. These key tenets/characteristics are based on lessons learned from industry in integrating the Commissioning Process into an Owner's procurement process. The key tenets are:

- Must define the end goal – in order to achieve success at the end of a project it is critical that the criteria for success be defined at the project inception. If the goal is not clearly understood and conveyed to all, then it will never be achieved.
- Work done right the first time – rework is more costly in time and dollars than doing work right the first time. Therefore, the second key characteristic of a quality process is that the process activities must enable the individual programmers/planners, architects, engineers, designers, technicians, vendors, manufacturers, and installers to avoid rework by having the required information. This applies to programmers in pre-design and architects and engineers during design, to prevent concepts, plans and specifications that are reworked as needs are defined after the fact, since they initially did not clearly express the Owner's requirements.

- Each individual worker is responsible for quality – critical to any quality process is to realize that quality cannot be dictated, but is determined at the lowest level. It is the draftsman and tradesman that determines the level of quality achieved as they physically accomplish the work. Therefore, it is at the individual level that we must focus on conveying the success criteria and evaluating the work against such criteria.
- Verification of work, not inspection – consummate with the previous characteristic, it is not possible to inspect quality into the project – all that an Owner can do is verify that the work completed achieves the defined level of success. Further, verification is a continuous process to identify and resolve systemic issues before they become problems. This avoids coming in at the end of pre-design, design or construction, finding mistakes, and pointing fingers. The goal of the Commissioning Process is to prevent this from every happening by making the delivery a Commissioning Team effort, not doing-inspection-confrontation.
- Focus on life of item, not first day of use – a quality process is holistic in that the best solution for the facility is to focus on the life of the facility, not just first cost. While budgets are always limited on school projects, the best solution is almost always one that has the lowest life cycle cost – schools remain for 30 to 50 years with the operating costs equaling up to 96% of the design, construction, and operational costs.
- Improved quality results in lower project costs – the bottom line is that if an improved procurement process does not reduce costs for the Owner, design professionals, and contractors, it will not be adopted. Therefore, the final key characteristic of a quality process is that it must result in lower project costs for the Owner, with design professionals and contractors having a higher margin.

### ***The Commissioning Process – An Owner’s Quality-Based Procurement Process***

In order to understand the Owner’s responsibility in the procurement of a facility, it is important to understand how a typical project is currently procured and then how the Commissioning Process is used to implement/improve an Owner’s quality -based process. Figure 1 details the functional design and construction activities accomplished by the design professionals and contractors and the Owner’s procurement process activities.



Courtesy of Farnsworth Group  
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Figure 1: Owner's Quality-Based Procurement Process

## Functional Design & Construction

The functional design and construction activities are those that are traditionally completed by design professionals and contractors, either through a design-bid-build, design-build, or similar contracting mechanism.

The responsibility of the design professionals (architect and engineers) is to decipher the Owner's vision and create construction documents that can convey the vision to a contractor. The contractor's responsibility is to then construct the facility as detailed in the construction documents. Once the facility is completed and systems started-up, the operation and maintenance personnel are responsible to operate the systems according to their training, systems manual information, and knowledge.

Absent an Owner's quality-based procurement process, the means in obtaining a facility is linear, transfers information from phase to phase, and relies upon key individuals to clearly understand and convey the Owner's needs, without a formal written document. Further, it is assumed that the construction documents completely and clearly convey the Owner's criteria to the contractor, and that the contractor subsequently conveys this to the operation and maintenance personnel.

This old process can be considered a "system of experts", where the Owner relies on key individuals for a perfect building. Unfortunately, this typically results in poor performing facilities, Owner's needs not met, and high conflict.

## Owner's Quality-Based Procurement Process

The solution to achieving successful facilities for the Owner is to have an "expert system" that enables the Owner to clearly define the success criteria and to verify that the programming professionals, design professionals, contractors, and the Owner's operation and maintenance personnel continuously achieve the criteria – this is the Commissioning Process.

There have been many previous approaches to implementing a quality process for delivery of construction projects. The goal of the formal Commissioning Process captures the best of these efforts, including the quality process used in manufacturing. It should also be noted that the Commissioning Process is continuously improving, and that any users of this Guideline should be open to documented improvements in the process. Further, users should be open to modifying the process to meet local needs, but not to shortcut the process to accommodate suggested modifications by those who are not experienced in leading and successfully implementing a cost effective Commissioning Process.

The Commissioning Process begins at the inception of a project and continues through the life of the facility. The key phases and activities of the Commissioning Process are:

- Pre-Design Phase (also referred to as the Planning or Programming Phase)
  - Goal Setting
  - Defining Roles and Responsibilities
  - Defining Documentation Requirements
- Design Phase
  - Verifying Design Achieves Goals
  - Detailing Owner Requirements in Construction Documents
  - Educating Potential Contractors
- Construction Phase
  - Building the Team
  - Verifying Construction Achieves Goals
  - Transition from Contractor to Owner (the transition may be a very formal Turnover sub-phase)
- Occupancy and Operations Phase
  - Documentation Upkeep
  - On-Going Verification of Goals
  - 10-Month Warranty Review
  - Continuous Quality Improvement
  - Continuous Verification that the Project Intent is Achieved

The remaining portion of this Guideline details these phases and activities for an Owner to adopt the Commissioning Process as their own for facility procurement or building construction projects.

## Pre-Design Phase

The importance of the pre-design phase to the success of the final facility cannot be over-emphasized. The majority of problems that occur in the design and construction of a facility can often be traced back to poor definition of success or misunderstanding by the design professionals as to what the Owner desired. During this pre-design phase the Owner's goals are determined and documented, roles and responsibilities clarified, and the documentation required during the design and construction phases determined.

### Goal Setting

The question that always arises when an Owner first adopts the Commissioning Process is “doesn't my architect do this?” The answer is no – your architect helps define the scope of a project and develops a basis for the design, but rarely determines the Owner's success criteria. A simple example is the best way to explain this.

During the definition of a project, the architect or mechanical engineer will inevitably ask if, or you will state that, you want a comfortable building. Seems simple enough. However, when you say comfort, the mechanical engineer immediately translates this to mean you expect ASHRAE (American Society of Heating, Refrigerating, and Air-Conditioning Engineers) Standard 55 to be followed, which is a temperature, humidity, and airflow range under a given clothing level.

However, what did you mean by comfort? For a past school, the top ten responses during a goal setting workshop were:

1. No complaints about temperature.
2. Good air circulation.
3. No transfer/proper filtration for bacterial and virus control.
4. Uniform temperature from room to room.
5. Adequate air change rates.
6. Adequate outdoor air.
7. Safe, clean, comfortable physical environment.
8. Correct, glare-free lighting levels to match use of room.
9. No odors (distracting).
10. No noise interference (acoustics).

As you can see from the list, the Owner was not concerned about what the actual temperature was, just that there were no complaints (operations and maintenance definition of comfort is when the phone does not ring). Therefore, it is not that the design professionals are not asking questions, it is that they are not obtaining responses in the Owner's language from all the unique Owner entities.

The Owner's goals and success criteria can be best determined through the development of a Project Intent document using the nominal group technique (Delbecq and Van de Ven, 1971) in a workshop format. The nominal group technique is a means to gather consensus and all ideas from a diverse group, using a brainstorming technique that:

- Obtains responses from all attendees
- Does not allow one person to dominate
- Determines individual needs
- Documents group ranking of needs

Use of the nominal group technique obtains the group's input and consensus quickly. Without this structure for the workshop, the key information would not be obtained and the document developed would contain the biases of the creator, resulting in a disappointed owner and disappointed users as their expectations are not met upon occupancy.

While the Project Intent is developed during the pre-design phase, as decisions and tradeoffs (e.g., between features and budget) are made during the design and construction phases, the Project Intent is updated to reflect those decisions. Therefore, the Project Intent document helps facilitate these decisions by illuminating the clear impact of

a decision (e.g., lower quality diffusers are chosen to save money at the expense of comfort). By updating the Project Intent document and providing these updates to the owner and users, expectations will be kept current and the project will be a success upon occupancy.

A key benefit of adopting the Commissioning Process is a greater interaction between the individual team members (Owner, users, designers, contractors, etc.) through the workshop. During the workshop, information is obtained that ranges from the basic functional requirements of the facility to how the owner and users define such items as comfort, green, efficiency, and success. As each project is unique in its requirements, the use of the same questions or method from project to project is not always appropriate. However, the same methodology for obtaining the information is used.

To properly develop the Project Intent using the workshop method requires the following steps be accomplished:

- Develop the Questions
- Organize the Workshop
- Convene the Workshop
- Transform the Results
- Present the Results
- Update the Procedures

It is absolutely critical that the procedure presented be followed. Based upon experience, whenever the procedure has not been followed, control of the discussion is lost and consensus or the information required is not obtained.

Details of accomplishing a Project Intent workshop are contained in *Appendix B: Project Intent Workshop*, with a sample Project Intent in *Appendix C: Project Intent Example*.

## **Defining Roles and Responsibilities**

A key Commissioning Process activity during the pre-design phase is to clearly define and document individual Commissioning Team member roles and responsibilities. This information is contained in the Commissioning Plan, which initially defines what are the major activities in the Commissioning Process, and becomes the final report at the end of the project.

The Commissioning Plan is intended to be the roadmap for the implementation of the Commissioning Process and to provide all team members with an understanding of what the process is and how they are involved in the success of the project. The basic outline of the Commissioning Plan is:

- Commissioning Plan Overview – provide an executive summary of the Commissioning Plan, including an overview of how to use the plan and who it is written for.
- Commissioning Process Description – provide an overview of the Commissioning Process, focusing on the philosophy that the Commissioning Process is the Owner’s quality-based procurement process and is intended to achieve success upon occupancy.
- Pre-Design Phase – detail the Commissioning Process activities that are accomplished during the pre-design phase. This should include how to develop the Owner’s Project Intent, the development and maintenance of the Commissioning Plan, and the creation of the Commissioning Process Issues Database.
- Design Phase – detail the Commissioning Process activities that are accomplished during the design phase. This should include how the Commissioning Authority reviews and has input on suggestions for modifying the project specifications, verifies the Basis of Design, accomplishes design reviews, and participates in the construction pre-bid meeting. There should be a pre-bid training session for all contractors and sub-contractors.
- Construction Phase – detail the Commissioning Process activities that are accomplished during the construction phase. This should include conducting a pre-construction meeting, review of contractor

submittals, the creation, tracking, and verification of Construction Checklists, verification of training, verification of the systems manual (includes O&M materials/manuals), and oversight and observation of some or all testing.

- Operations and Occupancy Phase – detail the Commissioning Process activities that are accomplished during the operations and occupancy phase. This should include development of the final Commissioning Process Report, site visits, verification that operations is per the Project Intent, completion of seasonal testing, on-going training, and a warranty review, and the facilitation of a lessons learned meeting.
- Contact Information – clearly document the complete contact information for each team member.
- Schedule Requirements – document the key Commissioning Process milestones, including design, construction, and operational dates and sequence of activities.
- Appendices – the following appendices are completed and updated as the project progresses:
  - *Appendix A - Owner's Project Requirements*
  - *Appendix B - Basis of Design*
  - *Appendix C - Project Specifications*
  - *Appendix D - Communication Structures*
  - *Appendix E - Roles and Responsibilities*
  - *Appendix F - Commissioned Systems*
  - *Appendix G - Commissioning Process Schedule*
  - *Appendix H - Pre-Bid Meeting*
  - *Appendix I - Pre-Construction Meeting*
  - *Appendix J - Submittal Review*
  - *Appendix K - Commissioning Process Issues*
  - *Appendix L - Construction Checklists*
  - *Appendix M - Tests*
  - *Appendix N - Training*
  - *Appendix O - Systems Manual*
  - *Appendix P - Meeting Minutes*
  - *Appendix Q - Correspondence*
  - *Appendix R - Warranty Review*
  - *Appendix S - Lessons Learned*

## **Defining Documentation Requirements**

During the pre-design phase it is important to clearly define the documentation requirements expected during the design and construction phases. Detailing this information as early in the project as possible minimizes misunderstandings of expectations and rework by the various team members. This provides quality guidance to the design team, to enable them to maximize their time on design requirements, creativity, and maximizing benefits; like energy use, sustainable features, and productivity of the school.

## **Design Phase**

The documentation received during the design phase consists of the Basis of Design and the design professionals' drawings and specifications. The Basis of Design is developed by the design professionals to document how they achieved the Owner's Project Intent and all assumptions made (codes, standards, design conditions). The design documentation must include clear guidance on how checklists will be used and processed, Commissioning Team meetings, training, information for and development of the systems manual, and role and expectation of all contractors and their vendors.

The expectations of the design professionals are to be inserted into the design professionals' scope of work. See *Appendix D: Design Submittal Expectations* for a sample of these expectations by major design submission. One item of interest is that the different design submittals are not listed by percent complete but using a title. This was intentional to avoid conflicts between the Owner and design professional of what exactly is meant by 35%, 65%, or

95%. In addition, it must be clearly stated how the Commissioning Authority team will review design submittals for the owner, including early request for additional design or documentation to support the design development, when it is discovered through statistical review that the first one or two samples are incomplete in relationship to the level of design submitted.

## Construction Phase

The documentation received during the construction phase consists of submittals, completed construction checklists, operation and maintenance information, documented test results, record documents, training, and final completion certificate. This information is provided to the Owner through the Commissioning Authority for review in achieving the Project Intent.

## Issues/Benefit Log

It is important to clearly document the benefits and value of the Commissioning Process. The primary reason for this is that when the Commissioning Process is properly adopted, no problems are apparent. Therefore, for each issue identified and resolved through the Commissioning Process, the avoided cost to the Owner, design professionals, and contractors needs to be documented. This includes capital cost, operating cost, maintenance cost, and design cost. This should include a range of benefits, with a clear description of the calculation. For example, if an item is identified during the pre-design phase, there may be an expectation that in if the Commissioning Process was not followed it would have been identified in early design, late design, early construction, late construction, or during occupancy. The cost to implement and the benefits to the school will likely vary for each of these. This requires a range of costs and net benefits be developed for each Commissioning Process item for the school.

For past projects, it has been found that the cost of the Commissioning Process is recouped somewhere between 50% and 80% completion of design and that by the end of the first year of operation a minimum of three times the cost has been avoided by adopting the Commissioning Process. The high side benefit has been as high as 200 times the cost of the total Commissioning Process.

See *Appendix E: Issues/Benefit Log Value Report* for a sample report showing the value of the Commissioning Project for a typical project.

## Design Phase

During the Pre-Design Phase the Owner's success criteria were developed and recorded in the Project Intent document. This provides the foundation from which the design professionals (architect and engineers) will develop their design philosophies and construction documents. During the Design Phase there are three main activities that are accomplished within the Commissioning (Owner's) process:

- Verifying that the design achieves the Owner's goals
- Detailing the Owner's unique requirements in the construction documents
- Educating the potential contractors in the Owner's unique requirements for this project

### Verifying Design Achieves Goals

From an Owner's perspective, it is important to review each design submittal using the same criteria. Therefore, in the Commissioning Process, the Project Intent is used as the source of success criteria in each design review. However, unlike most current design submittals, in adopting the Commissioning Process the Owner asks for additional information to make the design review easier and to hold the design professionals responsible for a quality deliverable. This is accomplished by having the design professional submit the following with each package:

- Design – the design documents, with the features detailed in their scope of work (Appendix D), are provided. These documents typically include the drawings and specifications.
- Designer Checklist – the design professional needs to provide a completed checklist indicating they have met the intent of the submission (Appendix D) and that all Project Intents have been achieved. Any outstanding issues are listed with recommendations for resolution included.
- Basis of Design – all assumptions, calculations, and means of achieving each Project Intent is included in a format agreed upon by the Owner. See *Appendix F: Basis of Design Sample* for a mechanical system Basis of Design example.

The primary purpose of a design review in the Commissioning Process is not to find all of the mistakes, but to evaluate the design professional's process for achieving the Owner's Project Intent. The design professional is responsible for providing a set of construction documents that properly convey your Project Intent to the contractor. If the design professional's internal process is not achieving this (what we are reviewing for), then the design professional must go back and review and verify all of their drawings, not just the instances discovered by this review. This goes back to the underlying quality characteristic that only the individual determines quality and as an Owner you can only verify you are receiving the expected level of quality.

Therefore, the design review process is a quality-based procedure utilizing a sampling strategy. Since the design professional is responsible for the delivered product, if at anytime during the review it is apparent the deliverable does not achieve the Project Intent and there are systemic issues with the design professional's process, then the package is returned for correction and resubmittal. There are four key steps to the design review:

1. General Review – the initial review is to accomplish a quick review of the entire drawing set to determine if basic quality items such as legibility, room number, labeling, and continuation of items from sheet to sheet is present. If this basic level of quality is absent, then it is a waste of time reviewing additional details, as much will change.
2. Coordination Review – if the general quality is good, then the second step is to accomplish a coordination review to determine if the various disciplines have coordinated their placement of items and integration of systems. Again, if this has not been accomplished, then a detailed analysis of a system is fruitless as something will need to change to be able to construct the systems and assemblies.
3. Discipline Review – the third step is to look at each discipline in detail to evaluate achievement of the Project Intent. This review evaluates a small portion of the drawings (10-20%) in great detail – reviews

assumptions, calculations, drawings, schedules, Basis of Design, and specifications for properly conveying and achieving the Project Intent.

4. Specification Review – while the specifications have been reviewed in part during the discipline review, it is important to systemically review the specification separately to identify extraneous information and the overall clarity of the specifications.

The detailed design review procedure is contained in *Appendix G: Design Review Procedure*, including the methods used for sampling the drawings and specifications to focus this effort.

### ***Detailing Owner Requirements in Construction Documents***

The second major Commissioning Process Activity accomplished during the Design Phase is to insert unique Owner requirements into the construction documents. The primary need for this insertion is that the design professional is concerned about the conveying standard needs to construct the facility to the contractor, whereas the Owner is more concerned about the facility's long-term operation. The key Owner's requirements to be included are:

- Pre-construction meeting – subsequent to the notice to proceed and prior to the start of construction it is critical to convene a pre-construction meeting to review the Project Intent, Basis of Design, and communication structures (how and when communication is accomplished) with the contractors. The Commissioning Authority, design professionals, and Owner need to present this information. The intent of the meeting is to build a cohesive team with a common vision for the project and to develop the foundation for resolving problems before they occur.
- Commissioning Process meetings – periodically throughout construction there will be Commissioning Process meetings to review the achievement of the Owner's Project Intent, to address systemic issues, and to focus on key milestones from the first day of construction. These meetings are typically held just prior to the contractor's progress meetings as this avoids additional travel and time from the contractors.
- Construction Checklist completion – as part of the component, system, and assembly installation the contractor is required to complete Construction Checklists documenting their progress and achievement of the Project Intent. These Construction Checklists are provided by the Commissioning Authority and detail key items to check during delivery, pre-installation, installation, and start-up that are essential for doing work right the first time and meeting the Project Intent.
- Systems Manual information – contractor are very good at installing and starting-up a facility, but often has little experience in the actual day-to-day operation of a facility. Therefore, in the Commissioning Process it is important to first clearly define what information is required for the long-term operation and optimization of the systems installed and then define the skill set required to accomplish the documentation creation. The best way to achieve good system documentation is to require the contractor to provide the required information (shop drawings, operation and maintenance information, installation information, manufacturer's technician manual, manufacturer's training video, part-load performance information, etc.) and have a separate entity develop the Systems Manual. An example scope of work for an Electronic Systems Manual is contained in *Appendix H: System Manual Scope of Work*.
- Training – the current method of training for the majority of projects is at best haphazard. In the Commissioning Process, significant effort is taken to understand the current knowledge of the operations and maintenance staff, what training has and has not worked in the past, and what specific training is required relative to the systems, makes, and models being installed. This training program is developed during the design phase and inserted into the project specifications providing the contractor with clear guidance on what, where, when, and how each session is to be conducted.
- Functional performance testing – after all systems have been installed, started-up, and tested, the contractor accomplishes various tests to document the installed and operated systems achieve the Project Intent. The test procedures are developed by the Commissioning Authority, reviewed and accepted by the contractor,

and implemented by the contractor under the direction of the Commissioning Authority. A sample functional performance test structure is shown in



- *Appendix I: Example Functional Performance Test Structure.*
- Warranty start date – a single start date for warranties needs to be clearly stated in the project documents. The intent of this is to simplify the Owner’s operation of the system. Regardless of when the manufacturer’s warranty starts, the Owner is more concerned about the warranty between themselves and the contractor – who is ultimately responsible for the installation. By clearly stating the start date (conditions of starting the warranties) in the project specifications, the contractor can decide if they must purchase an extended warranty from the manufacturer to protect themselves from manufacturer’s defects.
- Certificate of Completion – in the Commissioning Process there is a Certificate of Completion that the Owner, contractor, design professionals, and Commissioning Authority sign indicating that the project is complete and to the extent possible the Project Intent has been achieved. This is a formal ceremony indicating the facility goes from contractor operated to Owner operated.

The proposed changes to Division 1 specification sections are shown in *Appendix J: Division 1 Specification Changes*.

## ***Educating Potential Contractors***

As most contractors have not been involved with the Commissioning Process before (they may have been involved with extended end-of-project testing, but not likely the process), it is critical during the pre-bid meeting that all contractors who plan to bid the job be present to understand the changes on this project relative to past projects. During the pre-bid meeting the following relative to the Commissioning Process should be presented:

- Project Intent overview
- Basis of Design overview
- Pre-construction meeting
- Construction Checklist completion and review
- Training
- The Commissioning Team
- Commissioning Team meetings
- Functional Performance Testing
- Systems Manual documentation
- Benefits to all parties

Except for the Basis of Design presentation by the design professionals, all of these are presented by the Commissioning Authority.

It is very important to convey to the contractors that the Commissioning Process will reduce their direct and indirect costs and make the project go smooth. This is essential, in that if these benefits are not properly conveyed, the contractors will assume that the Commissioning Process will increase their cost to complete the specific project.

## **Construction Phase**

Typically, between 50% and 60% of a Commissioning Authority's time is expended in the Pre-Design and Design Phases of a project. The primary reason is things are cheaper to fix on paper than once installed or constructed. However, even if the construction documents perfectly represent the Owner's Project Intent, the contractor's internal processes may not enable the vision to be translated into reality. Therefore, there are key activities that must be accomplished throughout the Construction Phase to achieve the Owner's Project Intent. These include:

- Integrating the contractors into the current Commissioning Authority-Owner-design professional team.
- On-going verification that the contractor's process is achieving the Project Intent.
- Formal transfer from the contractor operating the facility to the Owner operating it.

As decisions and changes are made during the Construction Phase, the Project Intent and Basis of Design documents must be updated. This is accomplished by the Commissioning Team.

### ***Building the Team***

Since the Commissioning Authority, Owner, and design professionals have been working together for months on the project, it is critical to integrate the contractors into this team as quickly as possible. For design-build projects this is made easier by the fact that some contractors have been involved since day one, but others have not. The primary goal of building the team early is to develop relationships when there are no problems in order to easily handle the problems when they do occur.

The team building is begun through the convening of a pre-construction meeting where the Project Intent and Basis of Design are reviewed and communication procedures defined. However, building the team is an on-going effort from all parties involved. The responsibility of the Commissioning Authority is to periodically review the strength of the team and facilitate issue resolution throughout the Construction Phase.

### ***Verifying Construction Achieves Goals***

Similar to verifying the design documents properly conveyed the Owner's Project Intent, the Commissioning Authority periodically evaluates the contractor's processes for achieving the Project Intent. This is accomplished during each site visit by verifying the completion of the Construction Checklists and record document upkeep. Since the contractor is responsible for installing and starting-up 100% of the systems and assemblies, the Commissioning Authority's responsibility is to sample the construction and evaluate achievement of the Project Intent. Any systemic errors must be clearly documented and resolved as soon as possible to avoid costly, if not impossible, changes.

Using a consistent site visit procedure where the recent construction is randomly sampled to verify achievement of the Project Intent is critical to the success of the Commissioning Process. The importance is that we institute the expert system and not rely on a system of experts to find all the problems. A sample site visit procedure is shown in *Appendix K: Site Visit Procedure*.

As the Construction Checklist forms the basis for much of the site visit procedure, an example is contained in *Appendix L: Example Construction Checklist*.

In addition to the physical facility verification, the Commissioning Authority is also responsible for verifying the training achieves the Project Intent and the Systems Manual is properly developed and meets the original expectations.

## ***Transition from Contractor to Owner***

The key to a successful project is that the Owner's Project Intent is verified continuously through Pre-Design, Design, and Construction. By accomplishing this verification and focus on the Project Intent expectations are kept equal to reality. Further, issues are identified, tracked, and resolved early in the project. The end result is that at the end of the project when the facility is tested as a whole, the Commissioning Process is really what is being evaluated, not the facility. The two possibilities are:

- Few problems are found and the Project Intent is shown to have been achieved. This means the Commissioning Process worked and gets an A grade.
- Many problems are found. This indicates that while everyone was trying to do their best, the process failed to properly convey and evaluate the Project Intent. While the facility may still operate well and meet most of the Owner's needs, the Commissioning Process did not work and gets an F grade. If this occurs, the source of the failure in the process must be identified and action taken to eliminate for all future projects. This should never occur when the Commissioning Process is properly implemented, in that there are just too many opportunities to verify the quality of the delivered project. This only happens when the Commissioning Team's involvement is limited or undermined.

The primary activity to be accomplished for the transition from contractor operated to Owner operated is to perform functional performance tests on the facility to verify the Project Intent has been achieved. It is assumed that by this point in the project, training and system documentation has been completed and accepted. Functional performance tests are one of the most difficult aspects of the Commissioning Process in that they usually try to verify aspects of the facility that are not typically verified. For example, many current contractors can easily test a chiller or boiler for performance and show that it meets the energy efficiency intent of an Owner.

However, the real intent of an Owner is the energy efficiency of the chiller while providing a comfortable indoor environment for the occupants and minimizing the maintenance required over the short and long term. Therefore, the testing of the chiller (component) is part of the larger system (chiller, pump, coil, fan, VAV box, diffuser, and controls).

For this example, the functional performance test would focus on the comfort of the room under various operating conditions, with concurrent evaluation of the energy efficiency and operability of each component in the system. Therefore, if issues arise, the data has been collected and can be used to troubleshoot the issue relative to the Project Intent.

## **Occupancy and Operations Phase**

The Commissioning Process formally continues through at least one year of operation, with the Commissioning Process philosophy being used for the life of the facility. The first year is critical, as most warranties are still in effect and this when maintenance habits (typically bad ones) are formed, with the result being poor long term optimization and documentation maintenance.

### ***Documentation Upkeep***

The key underlying principle during the Occupancy and Operations Phase is that the operation and maintenance of the facility is continually compared to the Project Intent and Basis of Design. During this phase, it makes more sense to use the terms Operational Intent and Basis of Operation as these change through time and it is no longer a project or design with modifications and renovations to the facility.

Therefore, as a change to a space is recommended or required (additional students, new computers, rearranging floor layout, etc.) the new Operational Intent is compared with the current Basis of Operation. If the two do not match, then the Owner must either invest in the facility to improve the Basis of Operation or reduce their expectations (Operational Intent). For this process to succeed, good control and maintenance over the Operational Intent, Basis of Operation, and the Systems Manual is essential.

During the first year of operation the Commissioning Authority accomplishes periodic site visits (4 to 24) to train the operations and maintenance in how to maintain the documentation and to help troubleshoot any issues that have been identified. Since the Commissioning Authority has been involved in the project since day one, they are in the best position to provide the operations and maintenance staff with guidance on which contractor to contact and how to optimize system operation to maintain the Operational Intent.

During subsequent years, the Commissioning Authority accomplishes annual or semiannual site visits for verifying the documentation is still current and being used.

### ***On-Going Verification of Goals***

As many systems cannot be accurately tested during the off- or swing-seasons, on-going periodic testing of the systems using the functional performance test procedures is essential for identifying and eliminating degradation. During the first year it is recommended that at least the opposite season be tested. During subsequent years at reasonable intervals, the intermediate season shifts (Spring and Fall) need to be tested.

By training the operations and maintenance staff during construction, startup, and turnover, they are able to complete the tests themselves with little input. Further, this on-going training provides periodic evaluation of the facility with the original test benchmarks, or to establish new benchmarks after an Operational Intent change.

### ***Warranty Review***

Warranties range from 6-months to 1-year for most components and materials, with up to 40 to 50 years for some materials. To maintain the validity of the warranty and be covered under a failure, it is important to clearly sort the warranty information (Systems Manual) and document what should and should not be done.

Further, within two months of the warranty end date, and annually for the longer-term warranties, the Commissioning Authority (1<sup>st</sup> year) and operations and maintenance personnel perform the tests as defined during construction or as modified for a new Operational Intent. Any issues identified are brought to the contractor's or manufacturer's attention for resolution.

### ***Continuous Quality Improvement***

Since the Commissioning Process is based on quality principles, there needs to be continuous improvement of the way the activities are implemented based on lessons learned. Therefore, on an annual basis a lessons learned meeting should be held to determine if the Operational Intent is still valid, if there are any issues with the Basis of Operation, and what is coming in the next 12 months that need to be addressed.

At the end of the first year of operation, this Lessons Learned Meeting includes the design professionals, contractors, and Commissioning Authority. Subsequent meetings will primarily be composed of the Owner's personnel and users of the facility, with the occasional inclusion of a Commissioning Authority to aid in facilitating the process.

The key to the success of these lessons learned meetings is that a third party be the facilitator. The primary reason for this is that anyone involved in the project or facility will be biased and will tend to want to deflect criticism from themselves.

## Key Milestones

There are several key milestones that need to be included in the project schedule and construction documents relative to the Commissioning Process. The primary need for these milestones is that they avoid many of the end of project issues that are present on most projects by eliminating the issue early in construction. The milestones to be incorporated in the project schedule should include:

- Project Intent workshop
- Schematic design submittal
- Design development submittal
- Construction document submittal
- Pre-bid meeting
- Pre-construction meeting
- Commissioning Team meetings
- Training sessions
- Shop drawing submittals
- Commissioning Authority site visits
- Systems Manual initial submittal within XX days of notice to proceed
- Control system software submittal within XX days of shop drawing acceptance
- Special tests or code official inspection and acceptance
- Functional Performance Tests
- Systems Manual final submittal
- Substantial completion
- Certificate of Completion
- Warranty start date
- Occupancy
- Operational site visits by Commissioning Authority
- On-going training sessions
- Seasonal testing
- Initial Commissioning Process Report submittal
- Warranty review 2 months prior to end of warranty period
- Lessons-learned meeting
- Final Commissioning Process Report.

## Implementation Guide

As the Commissioning Process is being adopted by Owners as their quality-based procurement method, some guidance is required on how to adopt the Commissioning Process activities to the current process. The primary difficulty is that each Owner has a unique process with each one having different strengths and weaknesses. While there is not a single best way to adopt the Commissioning Process, the following is based on working with Owners and change management experts:

1. Understand Your Current Procurement Process – in a majority of cases, the true facility procurement process is understood by few and followed by less. Therefore, the first step in adopting the Commissioning Process is to understand what your current process actually is. This entails developing a flow diagram of how a facility is planned, designed, constructed, and operated. This flow diagram will enable you to quickly identify where the Commissioning Process Activities are required to be added to your current procurement process.
2. Form a Commissioning Process Team – form a team composed of a Commissioning Authority (internal or external depending upon internal knowledge and skill level – see *Appendix M: Qualification Based Commissioning Authority Selection* for details on locating and hiring a qualified Commissioning Authority), operation and maintenance, contracting, programming, inspectors, and users. This team would review the current procurement process to identify opportunities for the inclusion of Commissioning Process Activities (Commissioning Authority as the teacher).
3. Identify Projects – identify either existing buildings that do not work (Retro-Commissioning Process) or a project currently in design (at least not more than 25% through construction). Apply the Commissioning Process utilizing the team as your core resources. The intent of implementing the Commissioning Process on these initial projects is to train a core group that will internalize the changes through the development of guidelines and procedural changes.
4. Document Resolved Issues – using an agreed upon format, document the issues identified and resolved by using the Commissioning Process. Make sure that values (quantitative and qualitative) are associated with each issue.
5. Accomplish Lessons Learned Workshop – convene the key project players and the Commissioning Process Team on the completed project to identify what worked, what did not work, and how to do it better.
6. Develop/Modify Guidelines – based on the lessons learned and knowledge of the Commissioning Process Team, modify or develop guidelines for the planning, design, construction, and operation of facilities based on the Commissioning Process principles. This should include as a minimum Project Intent workshop guidelines, design professional submittal expectations, standard integrated specifications, construction checklists, and base test procedures.
7. Annual Review – reconvene the Commissioning Process Team on an annual basis to review the results of all project lessons learned workshops for changes to implement in the Commissioning Process. Document and incorporate changes into the guidelines.

A full adoption of the Commissioning Project takes most Owners between 3 and 5 years. To minimize wasted efforts it is essential to have a Commissioning Authority that has planning, design, construction, and operation experience as well as quality process, change management, and Commissioning Process training experience for the entire facility, not just specific subsystems.

A key aspect of adopting the Commissioning Process as your facility procurement quality control is that change will be required and that change is often resisted. Therefore, it is important it understand that conflict will arise and that it must be managed. The primary facilitator of this change will be the Commissioning Authority. The primary means of minimizing conflict through the Commissioning Authority includes:

- Focus on the process, not the people in resolving problems – when problems occur, the first reaction is to figure out who is to blame and who is going to pay for it. In instituting change, this is the last thing that you want to do. Therefore, the role of the Commissioning Authority is to focus on the process and have trust in the process. The goal is that the solution is first identified without assigning responsibility. This results in finding the best solution to the problem, then determining how to implement it and who is responsible.
- Check your ego at the door – a key source of conflict is between the design professionals and those that review their designs. Therefore, it is important when accomplishing the reviews that comments focus on the ability of the design to achieve the Project Intent and not get focuses on differences of opinions regarding system types, manufacturers, etc. The Commissioning Authority must recognize when a problem is more of a personality or opinion difference and when it is one party not understanding the Project Intent or point of view.
- Be flexible – as every Owner has a slightly different procurement process for facilities, the integration of the Commissioning Process is different for each project. Therefore, the Commissioning Authority must understand the current process and be flexible in integrating the Commissioning Process into it. Since it takes between 3 and 5 years for this to occur, not all changes can be implemented on the first project. Be flexible on what is done and what is not done and focus on the most severe systemic problems first.
- Learn from others – similar to being flexible, the Owner's current process will always have some good procedures. The Commissioning Authority cannot dismiss these outright, but must evaluate them in context to the quality process and how some will be used, some modified, some replaced, and some eliminated.

## **Roles and Responsibilities**

By adopting the Commissioning Process, the Roles and Responsibilities of the various team members are simplified compared to the incorrect view that the Commissioning Process Activities is inspecting all systems at the end of construction. The primary Roles and Responsibilities are shown below for the key team members.

### ***Commissioning Authority***

The primary role of the Commissioning Authority is to maintain the focus on the Owner's Project Intent. The Commissioning Authority verifies that the work being accomplished by others, be it the Owner, design professionals, contractors, or operation and maintenance personnel is of quality and achieves the Project Intent. The specific responsibilities include:

- Lead all Commissioning Process Activities
- Facilitate the Project Intent Workshop and document development
- Accomplish sample-based design reviews
- Provide additions to project specifications in support of Commissioning Process Activities
- Present Commissioning Process overview at the pre-bid meeting
- Present Commissioning Process implementation guidelines at pre-construction meeting
- Review shop drawing submittals for Project Intent issues
- Review Systems Manual draft
- Conduct Commissioning Process meetings as required
- Develop and provide contractor Construction Checklists
- Accomplish periodic site visits using sampling technique to verify Project Intent achievement
- Document all issues in issues database including value of resolving the issue
- Develop functional performance tests and review with contractor
- Review training materials
- Attend select training sessions
- Verify knowledge of operations and maintenance personnel after training session
- Review Systems Manual final
- Direct completion of functional performance tests
- Develop draft Commissioning Process report
- Conduct periodic site visits during first year of operation
- Be a resource to operations and maintenance personnel during the first year of operation
- Conduct seasonal testing with operations and maintenance personnel
- Attend lessons learned workshop
- Develop final Commissioning Process report

### ***Owner***

The Owner (occupants, users, contracting, and financial contact) must provide personnel to participate in the Commissioning Process who can represent their organization's needs and desires and communicate decisions back to their organization. The key responsibilities of the Owner are:

- Participate in the Project Intent Workshop
- Be involved in design reviews
- Attend periodic Commissioning Process meetings
- Attend training
- Provide constructive comments during first year of operation
- Attend lessons learned workshop
- Support Commissioning Process adoption

## ***Design Professionals***

The primary role of the design professionals does not change – develop and create construction documents that properly convey the Owner’s needs and requirements. Their responsibilities relative to the Commissioning Process include:

- Participate in the Project Intent workshop
- Develop the Basis of Design
- Maintain the Project Intent document
- Respond to Commissioning Authority design review comments
- Integrate Commissioning Authority specification additions and changes
- Participate in the pre-bid meeting
- Participate in the pre-construction meeting
- Provide 1-line diagrams for Systems Manual
- Participate in select Commissioning Process meetings
- Conduct Basis of Design training
- Attend lessons learned workshop

## ***Contractors***

All contractor Commissioning Process requirements must be in the construction documents or they will not be liable or responsible for accomplishing the activities. The requirements of vendors, suppliers, and manufacturers of materials and equipment must be clearly stated in the specifications. This includes expectations for submittals, training, warranties, shop drawings, operations and maintenance materials, and functional expectations (access, constructability, and maintainability). The contractor's primary role is to construct and start-up the facility. Their supply vendors’ and supporting manufacturers’ role is to furnish materials, assemblies, equipment, and systems that fully meet the Owners Project Intent. Their key responsibilities relative to the Commissioning Process include:

- Attend pre-bid meeting
- Attend pre-construction meeting
- Integrate milestones into construction schedule
- Provide Commissioning Authority with all shop drawings, requests for information, and change orders
- Provide information for Systems Manual
- Develop training program
- Participate in Commissioning Process meetings
- Complete Construction Checklists as work is completed
- Approve functional test plan
- Implement the functional test plan under the direction of the Commissioning Authority
- Attend lessons learned workshop

## ***Operation and Maintenance Personnel***

The primary role of the operations and maintenance personnel is to prepare themselves for taking the operation of the facility over from the contractor prior to occupancy and to optimize system operation according to the Project Intent. The key responsibilities of the operations and maintenance staff relative to the Commissioning Process include:

- Participate in the Project Intent Workshop, including training plan development
- Review design submittals for maintainability
- Attend the pre-bid meeting
- Attend the pre-construction meeting
- Participate in periodic site walkthroughs
- Participate in select Commissioning Process meetings
- Participate in periodic training sessions
- Accomplish seasonal testing under the direction of the Commissioning Authority
- Attend lessons learned workshop
- Maintain Operational Intent and Basis of Design documents and the Systems Manual

## **Community**

For most facilities, but especially for schools, the community's involvement is critical to the success of the project. This is due to the fact that the facility is typically constructed around and near other facilities and homes. The disruption of demolition, construction, and the use of the facility must be addressed, as well as the use of the facility by the community. The primary role of the community is to provide constructive input to the project and to define what value is, and how success will be evaluated throughout the project. The key responsibilities of the community representatives are:

- Communicate decisions and reasons to the community
- Participate in the Project Intent Workshop
- Participate in periodic site walkthroughs
- Participate in select Commissioning Process meetings
- Participate in periodic user training sessions
- Attend lessons learned workshop

## Electronic Tools

In order for the Commissioning Process to be easily implemented over a wide range of projects and to easily create forms and track completion items and resolution of issues, electronic tools may be implemented. There are two distinct, yet related, electronic tools that are important for an Owner to adopt the Commissioning Process. These are:

- Commissioning Process facilitator – this electronic tool is intended to create and track all information required or produced during the Commissioning Process. This includes the Project Intent, Basis of Design, issues, Construction Checklists, site visits, Commissioning Process meetings, functional test procedures, and results of training. The primary benefits of this tool are that “things aren’t missed” and at the end of the project the database of information is provided to the Owner as a clear and concise record of the project.
- Systems Manual creator – there is a significant amount of information required to properly operate, maintain, and optimize a facility. Typically this information is hard to navigate and find the data that is required to solve a particular problem. The Systems Manual creator is used to develop an electronic version of the Systems Manual that is searchable, graphically based, and contains all the information on each component and system available to aid the operations and maintenance staff in doing their job.

### ***Commissioning Process Facilitator***

Several Commissioning Authority firms have developed internal software to make their work manageable. While few are available on the open market, most firms provide the electronic documentation/results of a Commissioning Process project to their clients at the end of the project. Some also sell the software as a separate service. The discussion in this section is intended to be generic to provide an understanding of what a Commissioning Authority’s electronic tool should accomplish and provide for an Owner.

Each of the project phases should be readily accessible from a single interface screen. Each of the project phases then has the specific activities that are accomplished or facilitated by the program. The following are typically included:

- Pre-Design
  - Project Intent
  - Commissioning Plan
  - Specification development
- Design
  - Basis of Design
  - Design review comments
  - Construction Checklist builder
  - Create contractor’s database
- Construction
  - Construction Checklist tracking
  - Site visit records
  - Training program records
  - Schedule verification
  - Witness of testing
- Turn-Over
  - Functional performance tests
  - Final review of record documents

- Certificate of Completion
- Draft Commissioning Process report
- Post Construction
  - Operational site visit records
  - Seasonal functional performance testing
  - Warranty review
  - Lessons learned meeting
  - Final Commissioning Process report

A primary benefit of an electronic database is that all correspondence, both incoming and outgoing, can be tracked and maintained in the database. Therefore, searching of documents is made easier and the Owner has future access to all of this correspondence.

In addition, it is critical to identify, track, and resolve systemic issues during the Commissioning Process, and to avoid having any issue fall through the cracks, a primary activity of the electronic database is to manage all the Commissioning Process issues.

The key components that must be documented for any issue includes:

- Title
- Dates found, response due, and resolved
- Who identified and is responsible for follow-up
- Value of resolving the issue
- Issue description
- Effects of issue
- Possible cause
- Recommendation
- Actions taken
- Final resolution
- Equipment associated with
- Priority

Another benefit of being electric is that pictures (scanned or digital) can be associated with any equipment or issue. Therefore, when an issue is documented, a photo of it can be e-mailed to the responsible party for resolution. This eliminates the need for a site visit and reduces overall resolution time.

The level of detail is only limited to the amount of information that is inserted for the issue. For example, on the value of the issue, the avoided cost to the Owner, design professionals, and contractor can all be detailed and included in the issue. In addition, since the issues are all date stamped, it is very easy to provide up-to-date information to the Commissioning Authority and other team members on the status of issues and which have been resolved, which are past due, and which are outstanding.

A summary report provided to the Commissioning Process Team is shown in Figure 2.

**Summary of Commissioning Issues Awaiting Response**

Wednesday, June 20, 2001

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**Issue Title:** M703, routing building EA into cooling tower well

**Description:** From this plan and your response to previous review comments, we understand that the energy recovery unit discharge from each unit is horizontal and into the cooling tower well or pit. We are concerned about routing the building exhaust air streams into the cooling tower which will act as an air washer. Are the upstream filters adequate to take care of potential contaminants? What about the general exhaust areas?

**Identified By:** Joe Lang      **Person Responsible:**

**Date Found:** Wednesday, December 27, 2000      **Response Date:** Saturday, June 30, 2001

**Date Resolved:**      **Issue Priority:** Medium

**Equipment Type:** 0      **Equipment Tag #:** 0

**Cost to Fix:** \$0      **Ongoing Cost Saved:** \$0.00

**Actions Taken to Resolve Issue:**

Friday, December 08, 2000      Clarification that EA is routed into the CT well

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**Issue Title:** M401, Difference steam pressures used

**Description:** There is a difference in the value of the steam pressure available at the humidifier and that at the heating coil in the AHUs. See note 1 for the humidifier schedule and note 8 for the AHU schedule.

**Identified By:** Chad Dorgan      **Person Responsible:**

**Date Found:** Friday, June 01, 2001      **Response Date:** Saturday, June 30, 2001

**Date Resolved:**      **Issue Priority:** Medium

**Equipment Type:** 0      **Equipment Tag #:** 0

**Cost to Fix:** \$0      **Ongoing Cost Saved:** \$0.00

**Actions Taken to Resolve Issue:**

**Figure 2: Commissioning Process Issue Report**

In addition to the Commissioning Process issues, the creation and tracking of Construction Checklists is the other information intensive activity of the Commissioning Process. To minimize the effort required, the electronic tool should contain a master library of Construction Checklists that are copied to a specific project. Again, since all information is electronic, the progress of completing the Construction Checklists can be easily tracked and reports provided to the Owner, design professionals, and contractors either periodically or through accessing a project website. Figure 3 contains a sample Construction Checklist completion summary report, with the "X's" indicating the task was completed.

Tracking Card Completion Report															
School City of Hammond															
Clark Middle and High School															
Wednesday, June 20, 2001															
Equip Type:	Tag Number:	1A	2A	2B	2C	3A	3B	3C	3D	3E	3F	3G	3H	3I	3J
Air Handling Unit	AHU-A1	X	X					X			X	X			
Air Handling Unit	AHU-A2	X	X					X			X	X			
Air Handling Unit	AHU-A3	X	X	X							X	X			
Air Handling Unit	AHU-A4	X	X	X							X				
Air Handling Unit	AHU-B1	X	X	X				X			X	X			
Cabinet Heater	CH-A1	X	X	X											
Cabinet Heater	CH-A2														
Cabinet Heater	CH-A3														
Cabinet Heater	CH-B1														
Chiller	Chiller CH-1	X	X	X											
Chiller	Chiller CH-2	X	X	X											
Exhaust Fan	EF-A1	X	X	X			X								
Exhaust Fan	EF-A10	X	X	X			X								
Exhaust Fan	EF-A11	X	X	X			X								
Exhaust Fan	EF-A2	X	X	X											
Exhaust Fan	EF-A3														
Exhaust Fan	EF-A4														
Exhaust Fan	EF-A5	X	X	X			X								
Exhaust Fan	EF-A6	X	X	X			X								
Exhaust Fan	EF-A7	X	X	X			X								
Exhaust Fan	EF-A8	X	X	X			X								
Exhaust Fan	EF-A9	X	X	X			X								
Exhaust Fan	EF-B1	X	X	X			X								
Exhaust Fan	EF-B2	X	X	X			X								
Exhaust Fan	EF-B3														
Exhaust Fan	EF-B4	X	X	X			X								

**Figure 3: Construction Checklist Completion Summary Report**

Figure 4 contains a report providing a summary of the percent complete by equipment type. This information can be used by the Owner, design professionals, and contractors to verify the progress of construction against the project schedule.

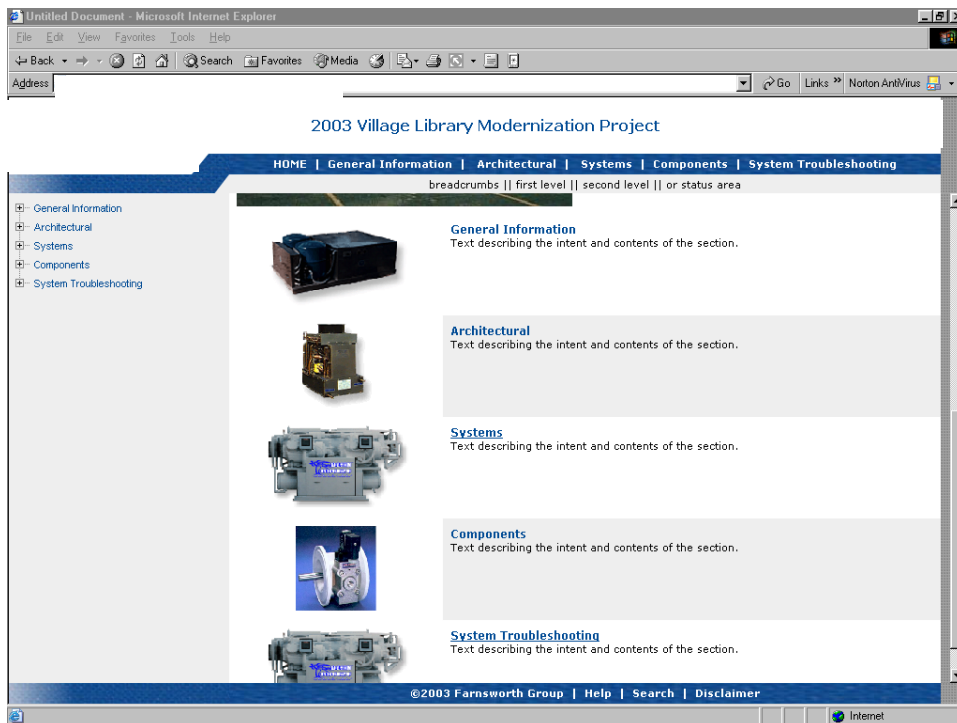
Percent of Equipment Complete Summary		
School City of Hammond		
Clark Middle and High School		
Monday, June 19, 2000 9:30 AM		
<b>Air Handling Unit</b>		
# of Equipment: 5	Completed Checklist Groups: 12 of 70	% Complete: 17.14%
<b>Cabinet Heater</b>		
# of Equipment: 4	Completed Checklist Groups: 3 of 44	% Complete: 6.82%
<b>Chiller</b>		
# of Equipment: 2	Completed Checklist Groups: 6 of 30	% Complete: 20.00%
<b>Exhaust Fan</b>		
# of Equipment: 15	Completed Checklist Groups: 25 of 105	% Complete: 23.81%
<b>Fan Coil Unit</b>		
# of Equipment: 1	Completed Checklist Groups: 3 of 12	% Complete: 25.00%
<b>Heat Exchanger</b>		
# of Equipment: 1	Completed Checklist Groups: 3 of 11	% Complete: 27.27%
<b>Kitchen Hood Ventilation System</b>		
# of Equipment: 3	Completed Checklist Groups: 18 of 27	% Complete: 66.67%
<b>Pump (In-Line)</b>		
# of Equipment: 2	Completed Checklist Groups: 10 of 14	% Complete: 71.43%

**Figure 4: Commissioning Process Issue Percent Complete Report**

## ***Systems Manual Creator***

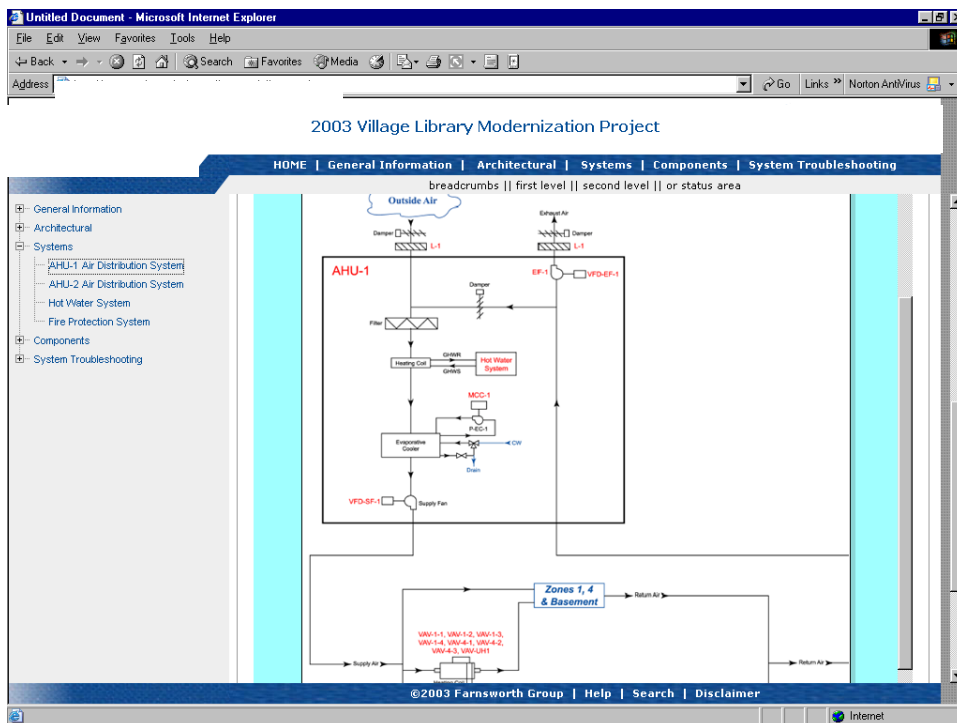
The second electronic tool that can be applied to a project is for the purpose of creating an electronic version of the Systems Manual. The intent of creating the electronic version is to make the data more accessible (any computer on the network), easier to navigate (search capability), and based on the systems installed, not the components. This enables the operations and maintenance staff to focus more on fixing the problems than providing temporary solutions.

The example electronic version of the Systems Manual example contained in this guideline is web-based and can be located on an Owner's intranet or placed on the internet for wider access (can password limit, just have access from any computer – home or work). Figure 5 contains a sample of the main screen of the one such Systems Manual.



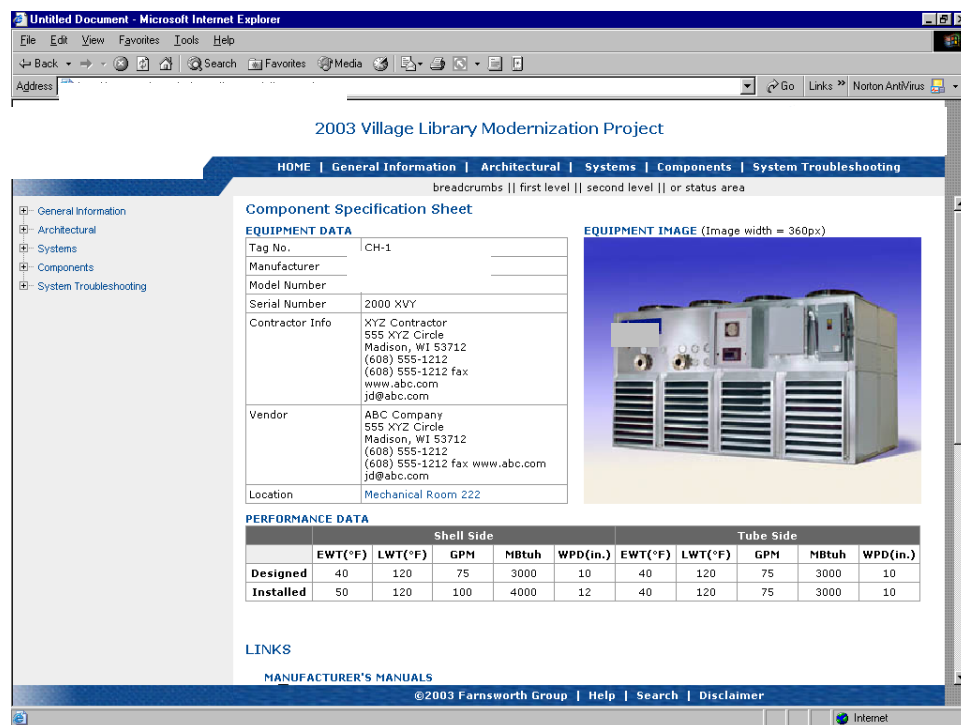
**Figure 5: Systems Manual Main Screen**

The primary benefit of the electronic version is that the information is organized on a system level instead of a component level. This enables the user to interface through diagrams and drop-down boxes. Further, the components on the 1-line diagrams are linked to more detailed pages, just by clicking on them. A typical system diagram page is shown in Figure 6.



**Figure 6: System 1-Line Diagram Interface**

Each individual component in the facility has a component specification sheet associated with it. This component specification sheet, as shown in Figure 7, includes equipment data, equipment image, performance information, and links.

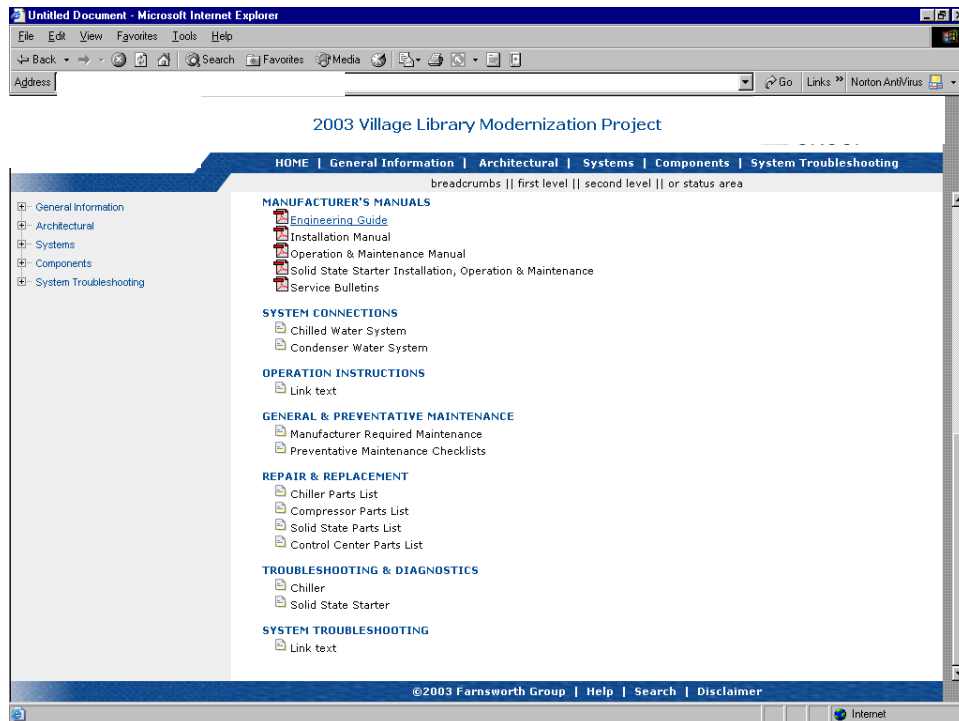


**Figure 7: Component Specification Sheet - Part 1**

The links on the component specification sheet includes:

- Manufacturer's manuals
- System connections
- Operation instructions
- General and preventative maintenance
- Repair and replacement
- Troubleshooting and diagnostics
- System troubleshooting

Figure 8 shows the typical component links in the Systems Manual.



**Figure 8: Component Specification Sheet - Part 2**

Unlike the current component based operations and maintenance manuals, the Systems Manual approaches the facility at a system level. This enables the troubleshooting of problems to be interfaced at a system level. For example, if a room is too hot, then it could be the thermostat, terminal unit, a damper, cooling coil, fan, pump, chiller, or air-cooled condenser. In addition, it could be a control or electrical circuit, or the use of the room is different than the original Basis of Design. Therefore, instead of having the technician go out and start opening and closing valves, the system-based information in the Systems Manual enables them to first identify the most likely cause and potential solution, then go out in the field and attempt changes.

A further benefit of the Systems Manual approach for a school district is with all of the key information located on a computer, the way operations and maintenance is managed can change. Instead of requiring talented, senior personnel to go from one problem to the next, they can assign their staff to these duties and they operate from a central location providing detailed guidance and direction. This is possible since they can access the 1-line diagrams and all the detailed information from their desk and guide their staff through troubleshooting remotely.

## Appendix A: CHPS Program Summary

The following table summarizes the Collaborative for High Performance Schools (CHPS) program. Essentially, it is the same format as the United States Green Building Council (USGBC) Leadership in Energy and Environmental Design (LEED™) with the use of prerequisites and the choice of credits to become certified as a CHPS.

CHPS Section	Title	Credits	Summary <sup>2</sup>
SITE (2 prerequisites; 14 possible points)			
Site Selection	Code Compliance	Req	Comply with all requirements of Title 5
	Sustainable Site Selection	1	No development on sites that are: prime agricultural land, in flood zone, habitat for endangered species, parkland
		1	Do not develop on greenfields
		1	Create centrally located sites within which 50% of students are located within minimum distances of the school
		1	Joint use of facilities
		1	Joint use of parks
		1	Reduced building footprint
Transportation	Transportation	1	Near public transit
		1	Provide bike racks & bike lanes for 15% of school population
		1	Minimize parking lot & create preferred parking for carpools
Stormwater Management	Construction Erosion	Req	Control erosion & sedimentation to reduce negative impacts on water & air quality
	Post-construction Management	1	Minimize runoff
		1	Treat runoff
Outdoor Surfaces	Design to Reduce Heat Islands	1	Shade or lighten impervious areas, OR reduce impervious parking
		1	Install cool roof
Outdoor Lighting	Light Pollution Reduction	1	Minimize outdoor illumination with no direct beam leaving site
WATER (1 prerequisite; 5 possible points)			
Outdoor Systems	Create Water Use Budget	Req	Establish & comply with water use budget
	Reduce Potable Water for Landscaping	1-2	Use high efficiency irrigation technology, OR reduce potable water consumption for irrigation by 50 or 100%
Indoor Systems	Water Use Reduction	1	50% reduction in potable water use for sewage conveyance with reclaimed water
		1-2	Decrease water use by 20 or 30% after meeting Energy Policy Act
ENERGY (2 prerequisites; 24 possible points; minimum 2 points required)			
Energy Efficiency	Minimum Energy Performance	Req	Design building to exceed Title 24-2001 by 10%, OR include prescriptive package of measures
	Superior Energy Performance	2	Exceed Title 24-2001 by 15%
		2	Exceed Title 24-2001 by 20%
		2-6	Exceed Title 24 2001by 25, 30 or 35%
		4	Alternate prescriptive method
	Natural Ventilation	1	HVAC interconnect controls with operable windows & doors
		3	Design 90% of classrooms without air conditioning
Alternate Energy Sources	Renewable Energy	2-6	5 to 50% of net energy use supplied by renewable energy or distributed generation
Commissioning & Verification	System Testing & Training	Req	Third party or district verification of building systems & training
	Commissioning	2-3	Basic commissioning tasks
	Energy Management Systems	1	Install an Energy Management System to measure & control loads
MATERIALS (1 prerequisite; 11 possible points)			
Waste Reduction & Efficient Material Use	Storage and Collection of Recyclables	Req	Meet local standards for recycling space & have spaces dedicated to recycling
	Site Waste Management	1-2	Meet local ordinances, develop waste management plan, & recycle 50 or 75% of construction waste
	Building Reuse	1-3	Reuse 75% or 100% of previous structure (+ 50% of non-shell systems for 3 points)
	Resource Reuse	1-2	Specify salvaged or refurbished materials for 5 or 10% of building
Sustainable Materials	Recycled Content	1-2	25 or 50% of building materials meet requirements
	Rapidly Renewable Materials	1	5% of materials are rapidly renewable
	Certified Wood	1	50% of wood must be certified

CHPS Section	Title	Credits	Summary <sup>2</sup>
INDOOR ENVIRONMENTAL QUALITY (3 prerequisites; 17 possible points)			
Daylighting	Daylighting in Classrooms	3	Minimum 2% daylight factor in 75% of classrooms
		1	Direct line of site glazing for 90% of classrooms
Indoor Air Quality	Minimum Requirements	Req	HVAC must meet Title 24 ventilation requirements, Cal/OSHA performance requirements, & satisfy ASHRAE 62 requirements for outdoor air supply
	Low-Emitting Materials	1-4	Building materials (paints, ceiling tiles, carpet, adhesives, etc.) meet chemical emission rates detailed in CHPS material specifications
	Pollutant Source Control	1	Control dust, segregate pollutant sources, local exhaust in kitchens, appropriately plumbed drains in chemical storage areas
		1	Install ducted HVAC returns
		1	Use high efficiency filters
	Construction IAQ Management Plan	1	Create & implement specified construction IAQ plan
		1	Flush out building or conduct IAQ testing
Acoustics	Minimum Acoustical Performance	Req	Classrooms must have a maximum (unoccupied) noise level of 45dbA, with maximum (unoccupied) reverberation times of 0.6 sec.
	Improved Acoustical Performance	1	Classrooms must have a maximum (unoccupied) noise level of 40dbA, with maximum (unoccupied) reverberation times of 0.6 sec.
		2	Classrooms must have a maximum (unoccupied) noise level of 35dbA, with maximum (unoccupied) reverberation times of 0.6 sec.
Thermal Comfort	ASHRAE 55 Code Compliance	Req	Comply with Title 24 required ASHRAE 55-1992 thermal comfort standard
	Controllability of Systems	1	Operable windows in classrooms
		1	Temperature & lighting controls in all classrooms
DISTRICT RESOLUTIONS (10 possible points)			
Institutionalize High Performance	District Resolutions	1	Institutionalize High Performance Goals on a district level
Indoor Air Quality	IAQ Management Plan	1	Create IAQ Management Plan and include in Facility Maintenance & Commissioning Plans Designate a trained staff person with clear responsibility to implement & update the plan
Maintenance	Maintenance Plan	1	Create a maintenance plan that includes an inventory of all equipment in the school & their preventative maintenance needs
		1	District allocates budget to fund plan at 100%
Energy	Equipment Performance	1	Require Energy Star equipment & prohibit wasteful technologies
		2	Require new equipment to be within 20% of EPA Energy Star "best available" for the category
	Green Power	2	Engage in a two-year power contract to purchase power generated from renewable sources approved by CEC
Transportation	Buses & Alternate Fuels	1	Provide busing service
		1	20% of bus & maintenance vehicle fleet serving the school must use alternative fuels
TOTAL (Minimum points required for CHPS school is 28 of possible 81)			

Therefore, the goal is to accomplish the prerequisites and to choose from the available credits to have at least 28, 2 of which must be from the energy category. It is important to realize that for some locations some of the prerequisites, such as Thermal Comfort, make it difficult to achieve some of the credits, Natural Ventilation – 90% of classrooms without air conditioning.

Also, it is important to understand that the commissioning prerequisite and credits of CHPS (under Energy) is always attained when the Commissioning Process as defined in this Guideline is adopted and implemented. While primarily only under the Energy section in CHPS, the Commissioning Process is critical to the success of any CHPS project as the technologies being used are typically new to the designers, contractors, and owners, and without the focus of the Project Intent and on-going verification, the CHPS goals are difficult to consistently achieve.

Further, through the convening of the Project Intent workshop, the Owner takes possession of the sustainability goals. Instead of just utilizing the previous CHPS checklist, the workshop will determine how the Owner defines sustainability in their own words. These criteria for sustainability are then applied to the CHPS checklist to determine the resultant score. Using this procedure minimizes the likelihood that the sustainability features will be cut later in the project as decisions of scope, budget, and schedule are required.

## Appendix B: Project Intent Workshop

The Project Intent workshop is composed of the following steps:

- Develop the Questions
- Organize the Workshop
- Convene the Workshop
- Transform the Results
- Present the Results
- Update the Procedures

### ***Develop the Questions***

The questions for the workshop need to be broad in nature in order to elicit discussion among the workshop attendees. In addition, a broad question is more likely to obtain a variety of viewpoints and not lead the attendees in a single direction. Therefore, careful consideration of the question content and wording is required.

The development of questions first requires the topic areas to be identified. For schools, the general topics would include educational environment, safety, and durability. In order to provide guidance in the development of questions for the workshop, examples are provided below for facility uses, occupant comfort, and project success.

- Facility uses – the purpose of this question is to understand the use of the facility from the perspective of all its users.

Three questions that could be asked to obtain this information are:

- a) What do you do in the facility?
- b) What are the functional requirements of this facility?
- c) What equipment is in the facility?

Question A is too narrow in that it focuses the workshop attendees only on their particular area or use of the facility and does not look at the facility as a whole. An example problem that would occur if this question is used would be ignoring the common areas. The attendees focus so much on their own areas and what they do, they forget about the synergies between the different groups. Question C is even worse. Asking about what equipment is in the facility does not get to the functionality of the facility.

Question B is the one to ask. All facilities have functional uses that must be provided in order for the organization (occupants) to be successful. Keeping the question broad, and even a little vague, enables the workshop attendees to fill in the blank using their knowledge and perspective. For example, it is not necessary to provide a definition of functional use of a facility. However, an analogy is often appropriate (e.g., some of the functional uses of a fast food restaurant are preparation area, ordering area, eating area, restroom, and storage).

- Occupant comfort – the purpose of this question is to determine how the occupants of the facility define their comfort.

Three questions that could be asked to obtain this information are:

- a) At what temperature are you comfortable?
- b) What conditions are important to your comfort in an ideal facility?
- c) Do you dress differently in the summer versus winter?

Again Question A is too narrow in that it focuses the attendees only on one aspect of comfort.

Allowing the attendees to define comfort on their own terms often results in unique responses designers and commissioning authorities never think of. One such example is when operations and

maintenance staff are asked Question B. Their response often is not a particular temperature or humidity value, but is “The phone does not ring”. This shows the importance of not trying to lead the discussion in the workshop. The reason the term “ideal facility” is used is to focus the attendees on what they want and not what is wrong with their current facility.

Question C is obviously too narrow as it only allows for a yes/no answer and no opportunity for interaction among the attendees.

- Project success – the purpose of this question is to determine how the different team members will define a successful project upon occupancy.

Three questions that could be asked to obtain this information are:

- a) What must be accomplished for a successful project?
- b) What must be accomplished to maintain budget/schedule?
- c) What must be done to avoid change orders?

Sometimes the most direct question is the best question. It is amazing how seldom the simple question of what is required for a successful project is asked. Designers and contractors typically assume that if they meet the budget or schedule and minimize change orders that the client will be happy. While these may be important aspects from the finance officer’s perspective, the occupants just want everything working from day one, to be comfortable, and to enjoy coming to work, whereas the operations and maintenance staff want to be properly trained, have good documentation, and to be able to easily find, access, and maintain the systems.

The questions typically used for our Project Intent workshops include:

1. What are the functional requirements of this facility?
2. What conditions are important to your comfort in an ideal facility?
3. What activities generate pollutants in this facility?
4. How will you benchmark the operation of the facility?
5. What can be done to make this facility more sustainable?
6. What problems with previous projects should be avoided?
7. What must be accomplished for a successful project?

## ***Organize the Workshop***

There are two key aspects of organizing the workshop: who to invite and how long should it be?

Who to invite is easy to answer – any group that will interface and interact with the facility and its use must be involved in the workshop. For example, for a typical school this would not only include the principal, vice principal, and operations and maintenance staff, but would also include administration staff, teachers, students, community groups, and parents – essentially anyone who will use the facility or is responsible for its operation. The difficult part is identifying the particular individual who will represent a particular group. This person must be knowledgeable of the group’s activities and needs, be able to speak for the group, and to communicate the results of the workshop and the Project Intent document back to their group. The best person often is not the manager of the group, but a line worker who deals with day-to-day problems the manager is unaware of. The difficulty is getting the manager to empower a representative and supporting this person in the workshop team’s decisions.

Since it is important to obtain as many viewpoints as possible, if the design or construction contractors have been hired, they should be invited to the workshop. This would include the architect, engineers, specialists, general contractor, sub contractors, and key manufacturers. **However, it is important that the design architect or engineer not be the facilitator as they need to be a participant of the workshop.**

Experience has shown that each question takes approximately 30 minutes to complete, ranging from 20 minutes to 45 minutes depending upon the number of attendees, the number of responses, and the discussion. For small

facilities (\$10 million and below), a half-day workshop is usually sufficient to obtain the key criteria. An additional half-day workshop is typically held with just the operations and maintenance staff to discuss the issues of training, documentation, and specific system requirements. For larger projects, a workshop is typically held with all of the key user groups to determine the facility requirements. Then, separate workshops may be convened with each major group to define that group's needs. Therefore, the workshop can last anywhere from one day to typically no more than five days.

Part of the organization effort is to invite the attendees to the workshop. The facility owner should do this in order to show the importance of this workshop. In the invitation, the attendee should be told the location, length of the workshop, and the basic structure. However, it is critical that the attendees not be given the questions ahead of time. By allowing the attendees to think about their answers, they become stubborn and believe only their response is the correct one. By providing the question and then obtaining responses immediately during the workshop, the attendees are open to all responses, resulting in the best possible group consensus.

### ***Convene the Workshop***

One item to keep in mind when convening the workshop is that attendees work harder and provide more interaction when they are comfortable. Therefore, selection of the workshop location must consider the room layout, comfort of the chairs, the lighting, ambient noise, and temperature control. In addition, food and drinks need to be provided, along with breaks to enable the group to interact between the questions.

In preparation of the workshop, several items need to be produced and brought to the workshop. These include:

1. Agenda – the agenda should include the time, place, invitees, and the key topics. However, the actual questions should not be shown, only Questions A, B, etc. The reason for this is to avoid having the attendees thinking about the future questions.
2. Sign-in sheet – the sign-in sheet should include the project name and date of the workshop and space for the attendees' name and e-mail (to send out results).
3. Pre-printed flip charts – Use PostIt™ flip charts, as these are easy to place on the walls and remove at the end of the workshop, and do not bleed through. Depending upon the expected size of the workshop, you will need between 4 and 5 flipcharts (60-75 response spaces). The first flipchart includes the questions and responses 1 through 15. The second flipchart includes responses 16 through 30, etc.
4. Attendee response forms – these are double-sided sheets, with the question and space for the attendees name, organization/department, and responses on the front, and the question and ranking table on the back.

The workshop is facilitated (not led) by the Commissioning Authority. In this role, the Commissioning Authority presents the questions, watches the time, records the responses, keeps anyone from dominating the discussion, and summarizes the results. For each question, the following procedure is used:

- Commissioning Authority states the question – In stating the question, the Commissioning Authority may need to provide analogies to get the attendees started. However, it is important to not lead the attendees to only a few answers. Therefore, for any guidance given, a different facility type should be used – if the project is a school, a fast food restaurant might be used as the example.
- Quiet response time (approximately 5 minutes) – The quiet response time where the individual attendees write down their responses on a piece of paper is important. This time enables the individuals to think of responses and essentially purge themselves of any possible response. It is important to not judge any response and consider that “all” responses are valid.
- Record individual responses on a flip chart with no discussion (approximately 10 minutes) – The recording of the individual responses on a flip chart without discussion is important in that it prevents one person from dominating. It is critical that the Commissioning Authority goes from attendee to attendee and only obtain one response at a time. Once each attendee has provided one response, start

over from the beginning to get a second response. This continues until all responses are obtained and documented. Even if a response appears to be similar to a previously recorded answer, avoid the urge to combine them at this step. By combining answers, the Commissioning Authority is introducing bias into the process. Additionally, not having any discussion provides the opportunity for shy individuals to provide their input, as they will not be questioned or ridiculed for “wrong” answers. It is recommended to mix up the starting position and direction of obtaining responses so that each person gets to go near the start or near the end of a round.

- Discuss the responses (approximately 5 to 10 minutes) – Once all the responses are recorded, the group reviews the responses one by one. This is where responses are grouped together and clarification is provided on what an item means. If the attendees think of additional responses during the discussion (this often happens), they are recorded. It is important for the Commissioning Authority to keep the discussion on the topic and not get mired down in politics or past history. The goal of the workshop is to identify the needs of the new project, not past ones.
- Individual ranking of the top 5 responses (approximately 5 minutes) – Once all attendees understand all of the responses, each attendee is asked to choose and rank their top five responses. Sometime during the workshop, the Commissioning Authority should state that all responses will be used in the development of the Project Intent. The ranking of the items is for the purpose of focusing the design and construction teams on the key criteria.

To properly facilitate the Project Intent Workshop requires three people – the Commissioning Authority as the facilitator, a chart recorder, and a computer recorder. The chart recorder allows the Commissioning Authority to focus on maintaining control of the workshop and ensures the process is followed. Further, the chart recorder strictly records each response as stated by the attendee or summarized by the Commissioning Authority. The computer recorder enters the information into the spreadsheet so that the results can be presented to the attendees at the completion of the workshop.

### ***Transform the Results***

Obtaining information from the workshop attendees is the simple part. The hard part is transforming these criteria into the Project Intent document. For the Commissioning Process to be successful, the Project Intent must contain criteria that are measurable, verifiable, and documentable. Vague and undefinable criteria will frustrate the design and construction team and result in them ignoring the Project Intent document. Therefore, in developing the Project Intent document after the completion of the workshop, the Commissioning Authority must work with the entire commissioning team (workshop attendees).

For example, Table 1 provides the top ten responses to the question of how the attendees define comfort. As can be seen in the table, the responses are varied and cover relatively broad categories. It is the responsibility of the Commissioning Authority to expand these to clear and concise criteria. Even a simple response such as “view to outdoors” requires a better definition. Is this from the seated or standing position, should certain rooms not have views, and what entails a good or bad view? Therefore, the translation of the criteria takes a significant amount of time, iterative reviews by the various parties, and the knowledge of the Commissioning Authority.

**Table 1: Ranked Comfort Responses**

<b>Rank</b>	<b>Responses</b>
1	Workspace Ergonomics
2	Temperature
3	Privacy
4	Acoustics and Noise Control
5	Individual Controls
6	Computer Reliability
7	Customer Comfort
8	Security
9	View to Outdoors
10	Ventilation (fresh air)

Since on most projects the design team has been hired at the time the Project Intent workshop is held, they are often participants in the workshop. An interesting result of this inclusion is that the ranking of the responses of the design team can be compared to that of the owner and users. It will be important to remember that the design team was completely involved in all workshop discussions and heard the same arguments and criteria as all others.

Table 2 contains the results for the functional use question from an actual workshop where the user, including the owner, and the design team (A/E) were involved. The table is sorted by the user's ranking, with the rankings normalized for differences in user to A/E group size. As can be seen, there are several responses the user thought were very important that the A/E did not rank at all, and vice versa. This is not to say that the user or the A/E have the wrong answer, just that they are approaching the project from different perspectives and will judge the success of the project using different criteria. Often, the owner, users, and design team let past bad experiences taint their perspective or jump to conclusions on what the needs are – they do not listen to what is being said.

This is a perfect example of why the current methods for obtaining project criteria do not work. The design team is in on the same discussions, yet comes up with different priorities. The Commissioning Process, through the Project Intent workshop and the creation of the Project Intent document, brings the owner, user, and A/E together to agree upon common criteria from which success will be defined.

**Table 2: Functional Use – User and A/E Rankings**

Rank	Responses	User Score	A/E Score	Overall Score
1	Employee Workspace	8.4	9.4	17.8
2	Comfort	4.4	2.7	7.1
3	Good First Impression	3.6	10.5	14.1
4	Privacy (acoustics)	3.2	2.3	5.5
5	Private Offices	2.3		2.3
6	Non-Obtrusive Smokers' Area	2.0		2.0
7	Larger Restrooms	1.9		1.9
8	Good Elevators	1.6		1.6
9	Security	1.5	1.2	2.7
10	Reliable Utilities	1.4	4.5	5.8
11	Dumpster	1.3		1.3
12	Technology	1.3	0.6	1.9
13	Interaction Among Agencies (co-location)	1.2	4.4	5.6
14	Flexibility for Future	1.1	4.7	5.8
15	Meeting/Conference Rooms	1.1		1.1
16	Consistent (non boring) Interiors	1.1	1.3	2.4
17	Showers	0.9		0.9
18	Operable Windows	0.6		0.6
19	Clear Definition of Public Areas		3.0	3.0
20	Easy Maintenance		2.4	2.4
21	Easy Customer Access		1.4	1.4
22	Communications		1.3	1.3
23	Good Envelope		1.1	1.1
24	Easy Access of Movement		1.0	1.0

## ***Present the Results***

Once the Project Intent has been drafted, it is provided to the workshop attendees for review and comment. Since the recipients of the Project Intent vary from the novice to the design and construction specialist, the format and presentation of the Project Intent is critical. It is recommended that the Project Intent go from general to specific to allow those not interested in the details to stop after the key criteria are presented.

In any project, it is typically possible to identify less than ten criteria that must be met in order to have a successful project. The Project Intent should start with these broad criteria and then provide additional details under each of the criteria. However, regardless of the level, the criteria must be measurable, verifiable, and documentable.

An example outline for a Project Intent is:

- Introduction – Includes an overview of the project and the general reasons why the project is being accomplished. A description of the owner's processes (Commissioning Process) is typically contained in this section.
- Key Project Intent – includes a listing of the key Project Intent which the Commissioning Process will focus upon and which the owner and the Commissioning Team have determined are critical to the success of the project.
- General Project Description - The size and scope of the project are included in this section.
- Objectives – The objectives for accomplishing this project are detailed in this section.

- Functional Uses – The expected functional uses (spaces and operations) for the facility are detailed in this section. A short description of each functional use is included to provide the context in which it was detailed.
- Occupancy Requirements – Includes the number of occupants (users and visitors) and the schedule of occupancy, including all special conditions.
- Budget Considerations and Limitations – The expected budgetary restrictions and considerations are contained in this section.
- Performance Criteria – The performance criteria for which the project will be evaluated by the commissioning team are included in this section. Each performance criterion should be measurable and verifiable.
  - General
  - Economic
  - User Requirements
  - Construction Process
  - Operational
  - Systems
  - Assemblies
- Project Intent Version History – Includes a summary of the changes made throughout the pre-design, design, construction, and occupancy and operations phases. This information is critical to understand and document the trade-offs made and the resulting impact on the project.

### ***Update the Procedures***

The last step when doing a workshop is to review the procedures used and update them based on lessons learned from the workshop. This step is typical of all quality processes where the procedures are always improved.

## Appendix C: Project Intent Example

### ***General Project Description***

CUSD Administrative Facility was originally constructed in 1957. Since that time, the primary purpose of the building has remained the same, but the building and its systems no longer meet the needs of the users. This project is a comprehensive modernization of the building, designed to extend its functional life and provide a safe and effective working environment for the entire staff. The building must be improved to meet current codes and standards and the current and foreseeable future requirements of the users, while maintaining the original historical appearance of the structure.

### ***Objectives***

There are several key objectives that CUSD wishes to achieve during this project. These include:

- a. Code compliance - Most of the CUSD Administrative Facility, including the fire alarm system, heating and cooling (HVAC), restrooms, elevators, lighting, etc., does not meet current building codes, standards, and accessibility requirements. Once this renovation project is complete, the building must meet all applicable codes, standards, and laws.
- b. Appropriate heating and cooling - The heating, ventilating, and air conditioning system in the building is no longer adequate for the current needs of the building users. This system must be upgraded to provide consistent and individually controllable temperature, humidity, and airflow at all times.
- c. Efficient and adequate work space - The existing layout of CUSD Administrative Facility's interior does not meet the needs of the current users. The spaces must be redesigned to provide ample work and support areas to facilitate the operations of the building rather than hamper them.
- d. Image enhancement – the CUSD Administrative Facility is the primary administrative building for the school district, housing the Superintendent's Office, Admissions, Public Affairs, Student Records, Personnel, Financial Management, Communications, Plans and Programs, Central Mail Room, and the Print Shop. Many of these organizations have direct contact with the public, such as the media, students, and parents. The image that the CUSD Administrative Facility projects must reflect the importance of the building and the overall image of CUSD. The renovated building shall be a showcase for providing value for the community's investment in their children.
- e. Flexibility - The many problems experienced by the current users of the CUSD Administrative Facility are primarily a result of a lack of flexibility in the original design of the interior spaces and systems. To prevent a repeat of this situation in the future, the new design for the building must be able to respond to the changing needs of the occupants. This includes flexibility in space layouts, heating and cooling systems, lighting, and utilities (phone, electric, data, etc.)
- f. Sustainability - The design and construction of the renovated building must take into account all long term and life cycle issues. The new building systems must be easily maintainable by the CUSD maintenance staff, with reasonable access to systems for routine maintenance. All building systems shall be designed and installed for the lowest possible life cycle cost, which takes into account both the first cost of the item/material and its long term operating costs. As a part of making the CUSD Administrative Facility a showcase and benchmark for all University projects, the materials, systems, and construction methods chosen for this project shall have the least possible environmental impact.

## **Functional Uses**

The functional uses of the CUSD Administrative Facility include those typical of a school district administrative office building, plus several specific uses defined by the individual user groups housed within the building. The functional uses common to most user groups include:

- a. Conference rooms - The current lack of adequate meeting space for the various tenant groups has resulted in inefficiency and scheduling difficulties.
- b. Offices - All user groups within the building require office space for their staff. The needs are a combination of private offices and open cubicle-style workstations.
- c. Storage space - Lockable storage space is a necessity for many tenant groups, and is at minimum very useful for all groups.
- d. Reception / Waiting areas - Obvious entrances with defined waiting areas are needed by all tenant organizations to help improve the professional image of each group and to guide building visitors.
- e. Break areas - The current lack of staff break areas has created problems for many groups, since the staff is forced to eat at their desks and use the bathroom sinks for kitchen needs.
- f. Copier / Equipment space - Each tenant organization requires designated locations for office equipment such as printers, copiers, and fax machines.

In addition to the functional areas defined above, the building as a whole requires a variety of support areas to allow each group to operate efficiently. These support areas include:

- g. Corridors - Corridors on each floor provide efficient movement throughout the building and between the building user areas. The corridors in the renovated building should be designed to prevent blind corners and collisions, and be wide enough to allow carts from the loading area to pass.
- h. Stairways and Elevators - The stairways and elevators provide efficient movement between the floors in the building. These features should be conveniently located for building egress and accessibility requirements.
- i. Public Restrooms - Public restrooms are needed for use by any building occupant or visitor. The restrooms must be conveniently located, clearly marked, and accessible.
- j. Custodial space - Closets or other designated custodial areas are needed on each floor to allow the janitorial staff to efficiently perform their duties without interruptions or inconveniences to other building staff.
- k. Mechanical rooms - Space must be designated within the building to allow for installation of mechanical equipment. This space should be optimally located to allow for the simplest and most efficient mechanical design.
- l. Electrical / Communications space - Each floor of the building must contain adequate space for installation of electrical and communications equipment. These spaces must be located in coordination with the Communications department to ensure that all user technology and utility needs are achievable.

Certain user groups within CUSD Administrative Facility also have specific requirements for spaces not categorized above. Each of these spaces is listed below according to the appropriate user:

### *Superintendent's Office:*

- a. Private Restroom - A private restroom is required adjoining the Superintendent and Vice Superintendent's offices.

#### *Print Shop:*

- b. Loading dock - The loading dock area is needed near the Print Plant to provide support to all building areas.

#### *Communications:*

- c. Document Imaging Service Center - This support area is needed by the Communications organization and is located next to the Print Shop.

### **General Quality of Materials and Construction**

Due to the expected use and longevity of the CUSD Administrative Facility prior to the next remodeling, the materials used must be of high quality, be durable and have low maintenance requirements. Emphasis is placed on receiving the highest quality, most cost effective materials possible to ensure the longevity of the systems and provide for years of reliable, simple operation.

The contractors shall be responsible for using the proper materials, personnel and techniques to construct a quality building. This quality can not be dictated, but must come from the contractors' processes and goals.

### **Occupancy Requirements**

The building is regularly occupied from 6 a.m. to 6 p.m., Monday through Friday. Depending on the activities of individual groups, the occupancy is occasionally extended late into the evenings and throughout the weekend. The peak occupancy requirements for the CUSD Administrative Facility are:

- 250 Staff
- 250 Visitors per day, average
- 10 Support staff (maintenance, custodial, etc.)

The occupancy schedule to be used to setup the control system is detailed in Table 1.

**Table 1: Occupancy Schedule**

Time	Morning Warm-up	Occupied	Special Event	IAQ Emergency
On	6:00 a.m.	7:00 a.m.	11:00 p.m.	Upon notice
Off	7:00 a.m.	11:00 p.m.	1:00 a.m.	2 hours later

### **IEQ Requirements**

It is imperative that the indoor environmental quality (IEQ) be maintained at a high level to provide the safest, most efficient working environment for the building users. The specific requirements to maintain good IEQ include:

- a. Temperature and humidity: The mechanical systems must be able to maintain a consistent set temperature in all rooms, throughout the entire day and all year. Each room temperature will be adjustable by room occupants within a 4°F range of the winter and summer set-points. The humidity of the spaces must not be allowed to exceed the designated set-point in order to maintain occupant comfort.
- b. Building envelope: It is essential to maintain quality workmanship of all insulation, weather stripping and caulking to ensure building infiltration is minimized. If this is not done, the building temperature requirements may not be met.
- c. Indoor air quality: Pollutants generated in the space shall be exhausted to the outdoors and not returned to the central air handling unit. The definition of pollutants includes, but is not limited to food odors, bathroom odors, printing odors (inks and toners), and excessive colognes and perfumes. There shall be no transfer of odors between spaces. Odors and fumes generated outside the building, such as vehicle exhaust or dumpster odors, shall not enter the building or mechanical system air intakes.

- d. Noise level: The background noise level in the office areas must be controlled both in the design and installation of the building systems. In addition, special attention must be given to the design of the offices and other work areas to provide maximum privacy.

## **Performance Criteria**

The performance criteria of which the success of the system will be measured include:

- a. Professional and industry standards: All work meets or exceeds ASHRAE 15-200x, 55-200x, 62-200x and 90.1-200x, NFPA and all local and state codes.
- b. Cost of operating: The cost to operate the building shall be 25% less than the current yearly average of \$3/ft<sup>2</sup>-year. Lighting levels, lighting load, chiller load and certain other major system components will be measured and checked against design criteria.
- c. Life cycle cost: The system shall be designed, constructed and operated to have the lowest possible life cycle cost within first cost budget constraints. Expected life cycles costs (net present value) are approximately \$245/ft<sup>2</sup> for a 30 year life cycle.
- d. Longevity: The major mechanical system components are expected to last at least 30 years without replacement assuming routine and preventative maintenance is accomplished. Individual components shall maintain calibration for a minimum of 1 year and shall not require replacement for at least 15 years. (May add criteria for life of envelope components-- curtain walls-- or electrical system components, or technology upgrades as needed)
- e. Temperature: Must be individually controlled for each room to maintain comfort during peak summer and winter conditions, as well as switchover periods. The temperature within a space is not to vary  $\pm 2^{\circ}\text{F}$  from floor to the occupied level (typically 7 feet) anywhere within the room or between spaces that have thermostats set at the same temperature. The space room temperature will be adjustable by room occupants within a 4°F range of the winter and summer set-points.
- f. Building envelope: The quality and integrity of the building envelope will be measured utilizing thermal performance and air integrity metrics.
- g. Relative humidity: The relative humidity within the occupied space shall not exceed 55% during summer operation. No minimum limit is required during winter operation (This is location and user dependent).
- h. Air distribution: There is uniform air distribution (within  $\pm 2^{\circ}\text{F}$  from set point) with no noticeable drafts or stagnant areas (no stratification) throughout the building.
- i. Occupants: There shall be complaints from no more than 5% of the building occupants due to comfort for the first year of operation. Ninety-five (95) percent of the occupants shall be comfortable at any given time.
- j. Air quality measurements: Representatives of the commissioning team shall walk into the building and 80% of them shall determine the indoor air quality to be satisfactory upon occupancy of the building and at the three, six, and 12 month point. The carbon dioxide (CO<sub>2</sub>) differential between indoors and outdoors shall not exceed 700 ppm.
- k. Noise level: The background noise level in the open type office areas (without any people) should be between 35 and 40 RC. In enclosed offices this value should be between 30 and 35 RC.
- l. Number of work orders: There will be no work orders resulting from improper design or poor installation. During the first 5 years of operation there will be no work orders resulting from the use of poor quality materials.

- m. Punch lists: There shall be no punch lists at substantial completion.
- n. Contractor callbacks: There shall be no need for contractor callbacks due to inadequate training, system fine-tuning, poor quality workmanship, improperly operating equipment, or uncomfortable conditions once occupancy has occurred.
- o. Number of days missed by all occupants: This number shall be 25% less than previously for this building (10 year average). (Absenteeism data must be available from CDS to measure before and after for the same building.)
- p. Training: The maintenance personnel trained on the system by manufacturers shall be able to train their peers to demonstrate the training sessions were effective. Training sessions will be video taped by the Commissioning Authority or representatives of CUSD. Training effectiveness will be verified by the Commissioning Authority through performance tests.
- q. Commissioning process: CUSD, architect, engineer, contractors, and Commissioning Authority shall be pleased with the results of using the commissioning process. A formal interview will be conducted following the project to obtain the opinion of involved parties. An evaluation will be written that will include lessons learned, features that were especially effective, and recommendations for improving the process on the next project.
- r. Room numbers: The room numbers on the construction documents for this renovation shall match actual numbering in the building. Also, the room numbers used in all documentation (O&M manuals, TAB report, etc.) shall be consistent.
- s. Control system: The control system shall function properly; building maintenance staff shall be able to operate the building efficiently, and the operating values displayed on screen, by system gauges, or printed in reports shall be accurate.
- t. Budget: The project shall be completed within budget with no change orders, except those initiated by CUSD. Recommendations for changes are invited and will be considered from any involved party provided that they benefit the overall quality, operating efficiency, or enhance the built environment.
- u. Schedule: The project shall be completed on time. The quality of the general contractor's overall project management will be monitored to ensure timely completion and orderly coordination between sub-contractors.
- v. Maintenance: The systems shall be easily maintainable with easy, identifiable access to all components. The Commissioning Authority will perform verification tests on system coding and marking.
- w. Project Record Drawings: The Project Record Drawings and documentation shall constitute an accurate representation of the system as it is installed. The project specifications require a separate set of up to date drawings to be maintained and located at the project site and at a specific location coordinated through CUSD. The Commissioning Authority and the project manager will periodically check to ensure these drawings are up to date and stored in the specified location. No components of the mechanical or electrical systems are to be buried or covered by other construction until the record drawings have been verified. Progress submissions will be required. Record drawings must be complete at substantial completion.
- x. Manuals: All manuals are delivered in their specified final form (both electronically and printed copies) at substantial completion and are tailored to the specific system/component.
- y. Valve chart: Accurate valve chart and graphics shall be provided in paper form for the O&M manuals. They shall be framed and mounted in mechanical rooms, and in electronic format to facilitate future changes.
- z. System integration: Interfaces between various systems shall work together properly.

### ***Budget Considerations and Limitations***

Budget constraints exist on all projects. For this project, the benefits of improvements must be weighed against their cost. CUSD wants to achieve the highest quality facility at the lowest possible investment. Any cost effective opportunity to improve the quality of the system will be welcomed for review.

As in other quality management systems, achieving or increasing the level of quality is accomplished by every worker on the project. This means that when anyone on the job identifies opportunities for improvement, or a potential problem, it should be brought to the immediate attention of the project manager or a member of the commissioning team. It may not be possible to incorporate every good idea on this project, but the knowledge gained will be beneficial to future projects. Potential problems that can be avoided are to everyone's benefit.

## Appendix D: Design Submittal Expectations

This appendix lists the items to be provided by the design professionals for each design submittal for the project. This list is not all inclusive nor is it limited to any items referred to or implied in the design professional's scope of work.

Item	Schematic Phase	Design Development Phase	Construction Document Phase
Specification	<ul style="list-style-type: none"> <li>System &amp; material narrative description</li> <li>Determine systems to commission</li> </ul>	<ul style="list-style-type: none"> <li>Outline specification</li> <li>Determine sections with Cx requirements, add outline of Cx requirements</li> </ul>	<ul style="list-style-type: none"> <li>Complete specification</li> <li>All Cx requirements included and OK'd by Commissioning Authority and owner</li> <li>Specification has been spell checked</li> <li>All temporary notes removed (??, "fix this", "to be added", etc.)</li> </ul>
CADD electronic files	<ul style="list-style-type: none"> <li>Samples of CADD files from all project consultants</li> </ul>	<ul style="list-style-type: none"> <li>Samples of CADD files corrected to meet Owner's standards</li> </ul>	<ul style="list-style-type: none"> <li>Complete &amp; accurate CADD files (all drawings)</li> </ul>
Drawings (general)	<ul style="list-style-type: none"> <li>Room numbers consistent</li> <li>Drawing index started</li> </ul>	<ul style="list-style-type: none"> <li>Add drawings dated and initialed</li> <li>Update drawing index</li> <li>Continuation notes are accurate</li> <li>Key plan and north arrows included</li> <li>Equipment tag numbers are unique</li> <li>Letter from cognizant authority approving room numbering provided</li> </ul>	<ul style="list-style-type: none"> <li>Revision notes are up to date</li> <li>Drawing index complete and verified</li> <li>Drawings are spell checked</li> <li>All temporary notes removed (??, "fix this", "to be added", etc.)</li> <li>Cross references complete and accurate (for detail drawings and cross sections)</li> </ul>
Site	<ul style="list-style-type: none"> <li>Existing conditions</li> <li>Site footprint</li> <li>Site entrance</li> <li>Demolition</li> <li>Site utilities</li> <li>Utility requirements</li> <li>Roads &amp; driveways</li> <li>Loading dock location (coordinate with HVAC outside air intakes)</li> <li>Future expansion</li> <li>Walkway locations</li> <li>Stairway locations</li> <li>Parking locations</li> <li>Waste collection locations (coordinate with HVAC outside air intakes)</li> </ul>	<ul style="list-style-type: none"> <li>Pedestrian circulation</li> <li>Utility details</li> <li>Dimensions</li> <li>Traffic flow plan</li> <li>Handicapped flow plan</li> <li>Lighting plan</li> <li>Stairway connections</li> <li>Waste Containers</li> <li>Site drainage</li> </ul>	<ul style="list-style-type: none"> <li>Pipe sizes</li> <li>Connection details</li> <li>Contractor parking</li> <li>Construction area</li> <li>Construction phasing</li> <li>Site development phasing</li> <li>Street use plan</li> </ul>

Item	Schematic Phase	Design Development Phase	Construction Document Phase
Landscaping	<ul style="list-style-type: none"> <li>Existing conditions</li> <li>Existing irrigation</li> <li>Irrigation legend</li> <li>Determine local code requirements</li> <li>Determine green building requirements</li> </ul>	<ul style="list-style-type: none"> <li>Irrigation plan</li> <li>Planting plan</li> <li>Implement green building requirements</li> </ul>	<ul style="list-style-type: none"> <li>Soil preparation &amp; planting specifications</li> <li>Guying details</li> <li>Piping diagrams</li> <li>Pipe sizes</li> <li>Design calculations</li> <li>Existing tree protection</li> <li>Calculations showing green building requirements are met (provide documentation for CHPS)</li> </ul>
Building Exterior Envelope	<ul style="list-style-type: none"> <li>Typical elevations</li> <li>Building cross-sections</li> <li>Fenestration layout</li> <li>Material designations</li> <li>Energy code requirements</li> <li>Green building requirements</li> <li>Historical requirements (renovations)</li> <li>Local / planning dept. requirements</li> <li>Roof layout</li> </ul>	<ul style="list-style-type: none"> <li>Typical wall sections</li> <li>Typical window details</li> <li>Exterior door details</li> <li>Roof &amp; drainage plan</li> <li>Parapet &amp; coping details</li> </ul>	<ul style="list-style-type: none"> <li>Roof details</li> <li>Exterior details</li> <li>Roof mounted equipment</li> <li>Flashing details</li> </ul>
Structural	<ul style="list-style-type: none"> <li>Structural scheme</li> <li>Written description including seismic analysis of existing bldg. &amp; proposed strengthening techniques</li> <li>Structural legend</li> </ul>	<ul style="list-style-type: none"> <li>Structural sections</li> <li>Typical floor framing plan</li> <li>Main member sizing</li> <li>Foundation Plan</li> <li>Fire proofing plan</li> </ul>	<ul style="list-style-type: none"> <li>Structural details</li> <li>Foundation details</li> <li>Beam &amp; column schedules</li> <li>Structural notes</li> <li>Calculations</li> </ul>
Building Interior	<ul style="list-style-type: none"> <li>Typical floor plans (min. 1/16" scale)</li> <li>Area use identification &amp; area in sq. Ft.</li> <li>Janitor closet locations</li> <li>Circulation paths</li> <li>Preliminary layouts for each major space type</li> <li>Show flexibility for expansion and alterations</li> <li>All room numbers</li> <li>Area tabulations compared to program requirements</li> <li>Cost study: existing, area separation, etc.</li> <li>Mechanical, electrical and other service closets and rooms</li> <li>Green building material selection requirements</li> </ul>	<ul style="list-style-type: none"> <li>All floor plans (min. 1/16" scale)</li> <li>Wall types, fire ratings, smoke control zones</li> <li>Partition types</li> <li>Defined seating, serving, &amp; kitchen facilities</li> <li>Fixed seating</li> <li>Equipment &amp; furniture layouts</li> <li>Material selection</li> </ul>	<ul style="list-style-type: none"> <li>Dimensioned floor plans</li> <li>Finish schedules</li> <li>Door &amp; hardware schedules</li> <li>Interior elevations</li> <li>Reflected ceiling plans</li> <li>Partition details</li> <li>Interior details</li> <li>Calculations showing green building requirements are met (provide documentation for CHPS )</li> </ul>

Item	Schematic Phase	Design Development Phase	Construction Document Phase
Elevators	<ul style="list-style-type: none"> <li>Elevator locations</li> <li>Equipment room locations</li> <li>Elevator legend</li> </ul>	<ul style="list-style-type: none"> <li>Elevator shaft section</li> <li>Equipment description</li> <li>ADA requirements</li> </ul>	<ul style="list-style-type: none"> <li>Dimensioned plans</li> <li>Complete specification</li> <li>Door &amp; frame details</li> <li>Interior details with lighting</li> </ul>
Plumbing	<ul style="list-style-type: none"> <li>Location of headers</li> <li>Location of pipe chases</li> <li>Fixture locations</li> <li>Mechanical legend</li> <li>Connection to utility</li> <li>Determine water pressure available at site</li> <li>Identify mechanical rooms</li> <li>Green building requirements for water usage</li> </ul>	<ul style="list-style-type: none"> <li>Water header diagram</li> <li>Piping plans</li> <li>ADA requirements</li> </ul>	<ul style="list-style-type: none"> <li>Pipe sizes</li> <li>Plumbing riser diagram</li> <li>Water header diagram</li> <li>Water heater piping detail</li> <li>Design calculations</li> <li>Pressure boost pump diagram (if required)</li> <li>DHW circ. Pump diagram (if required)</li> <li>Calculations showing green building requirements are met (provide documentation for CHPS )</li> </ul>
HVAC	<ul style="list-style-type: none"> <li>Evaluate system types and select system type to use</li> <li>One-line flow diagrams</li> <li>Energy code requirements</li> <li>Green building requirements for IAQ, energy</li> <li>Special occupancy zones</li> <li>Mechanical legend</li> <li>Identify mechanical rooms</li> <li>Air intake &amp; discharge locations (coordinate with loading dock and waste collection locations)</li> </ul>	<ul style="list-style-type: none"> <li>Central cooling water header diagram</li> <li>Steam / hot water header diagram</li> <li>Piping plans</li> <li>Preliminary calculations</li> <li>One-line duct layout</li> <li>Equipment list</li> <li>Equipment locations</li> <li>Control diagram</li> <li>Sequence of operation M/E smoke control scheme (matrix)</li> </ul>	<ul style="list-style-type: none"> <li>Central cooling water riser diagram</li> <li>Chilled water riser diagram</li> <li>Coil piping details</li> <li>Equipment details</li> <li>Calculations showing green building requirements are met (provide documentation for CHPS )</li> <li>Pipe sizes</li> <li>Equipment details</li> <li>Equipment schedules complete</li> <li>Installation details</li> <li>Cross sections</li> <li>Connection to FA &amp; MCC</li> <li>Design calculations</li> </ul>
HVAC Controls	<ul style="list-style-type: none"> <li>Determine modes of operation</li> <li>Desired setpoints</li> <li>Determine information to measure, items to control</li> <li>Graphical interface requirements</li> <li>Remote access requirements</li> <li>Interfacing requirements with existing control system</li> </ul>	<ul style="list-style-type: none"> <li>Specification requirements for materials</li> <li>Points list</li> <li>Preliminary sequences of operation</li> <li>Equipment safeties</li> <li>Sensor locations</li> </ul>	<ul style="list-style-type: none"> <li>Alarms</li> <li>Hours of operation</li> <li>Ramp up / down, delay, etc. time periods</li> <li>Lead / lag rotation method</li> <li>Final sequences of operation</li> <li>Occupied schedule</li> </ul>

<b>Item</b>	<b>Schematic Phase</b>	<b>Design Development Phase</b>	<b>Construction Document Phase</b>
Fire Protection (Mechanical)	<ul style="list-style-type: none"> <li>• Connection to utility</li> <li>• Location of sprinkler valve</li> <li>• Sprinkler legend</li> <li>• Determine local fire department requirements</li> <li>• Determine hazard classification</li> </ul>	<ul style="list-style-type: none"> <li>• Riser diagram</li> <li>• One-line layout</li> <li>• Equipment locations (pumps, control panels)</li> <li>• Connection to electrical power distribution</li> </ul>	<ul style="list-style-type: none"> <li>• Complete specifications</li> <li>• Sprinkler valve details</li> <li>• Header &amp; piping layouts</li> <li>• Pipe sizes</li> <li>• Design calculations</li> </ul>
Lighting	<ul style="list-style-type: none"> <li>• Zones w/foot-candles</li> <li>• Fixture, bulb, and ballast types</li> <li>• Energy code requirements</li> <li>• Green building requirements for lighting level and energy usage</li> </ul>	<ul style="list-style-type: none"> <li>• Fixture/switching layout</li> <li>• Light level calculations</li> </ul>	<ul style="list-style-type: none"> <li>• Fixture schedule</li> <li>• Installation details</li> <li>• Control diagram</li> <li>• Design calculations</li> <li>• Calculations showing green building requirements are met (provide documentation for CHPS )</li> </ul>
Electric Power Distribution	<ul style="list-style-type: none"> <li>• One-line diagrams</li> <li>• Electric vault location</li> <li>• Electric closet locations</li> <li>• Electric legend</li> <li>• Connection to utility</li> </ul>	<ul style="list-style-type: none"> <li>• Equipment layout/sizes</li> <li>• Panel locations/schedules</li> <li>• Floor plans</li> <li>• Power riser diagram</li> <li>• Load estimate</li> </ul>	<ul style="list-style-type: none"> <li>• Load summary</li> <li>• Panel schedules</li> <li>• Motor schedule</li> <li>• Connection to FA &amp; HVAC</li> <li>• MCC details</li> <li>• Design calculations</li> </ul>
Fire Alarm	<ul style="list-style-type: none"> <li>• Connection to utility</li> <li>• Panel location</li> <li>• Determine hazard classification</li> </ul>	<ul style="list-style-type: none"> <li>• Fire alarm zones</li> <li>• Smoke zones</li> <li>• Device locations</li> <li>• Riser diagram</li> <li>• ADA requirements</li> </ul>	<ul style="list-style-type: none"> <li>• Connection details</li> <li>• Connection to FA &amp; HVAC</li> <li>• Riser diagram</li> </ul>
Telecom	<ul style="list-style-type: none"> <li>• Building &amp; local distribution</li> <li>• Frame closet locations &amp; size</li> <li>• Cable tray outlet</li> <li>• Connection to utility</li> </ul>	<ul style="list-style-type: none"> <li>• Riser diagrams</li> <li>• Material cut-sheets</li> <li>• Conduit plans</li> <li>• Voice/data utility outlet locations</li> </ul>	<ul style="list-style-type: none"> <li>• Backboard layout &amp; connection diagrams</li> <li>• Connection details</li> <li>• Cable schedule</li> </ul>
Service Facilities	<ul style="list-style-type: none"> <li>• Loading dock</li> <li>• Service elevator</li> <li>• Service road</li> </ul>	<ul style="list-style-type: none"> <li>• Waste containers</li> <li>• Recycle holding area</li> <li>• Bottled gas area</li> <li>• Any special waste handling</li> <li>• Service vehicle parking area</li> </ul>	<ul style="list-style-type: none"> <li>• Details for all accessory &amp; support apparatus in each area</li> </ul>
Handicapped Provisions	<ul style="list-style-type: none"> <li>• Access locations</li> <li>• Restrooms</li> </ul>	<ul style="list-style-type: none"> <li>• Ramped accesses</li> </ul>	<ul style="list-style-type: none"> <li>• Details for all associated accessories &amp; provisions</li> </ul>
Personal Safety Provisions	<ul style="list-style-type: none"> <li>• Design considerations leading to an inherently safe occupancy environment</li> </ul>	<ul style="list-style-type: none"> <li>• Any special systems or applications promoting personal safety</li> </ul>	<ul style="list-style-type: none"> <li>• Details required for personal safety provisions</li> </ul>

Item	Schematic Phase	Design Development Phase	Construction Document Phase
Commissioning Process	<ul style="list-style-type: none"> <li>Attend project intent workshop</li> <li>Submit drawings to Commissioning Authority for review, respond to Commissioning Authority's comments</li> <li>Review Cx Plan, provide comments to Commissioning Authority</li> <li>Complete designer checklists</li> </ul>	<ul style="list-style-type: none"> <li>Review project intent, notify Commissioning Authority if a criteria can't be met</li> <li>Develop basis of design document</li> <li>Submit drawings to Commissioning Authority for review, respond to Commissioning Authority's comments</li> <li>Review Cx Plan, provide comments to Commissioning Authority</li> <li>Complete designer checklists</li> </ul>	<ul style="list-style-type: none"> <li>Review project intent, notify Commissioning Authority if a criteria can't be met</li> <li>Review basis of design document, notify Commissioning Authority if a criteria can't be met</li> <li>Submit drawings to Commissioning Authority for review, respond to Commissioning Authority's comments</li> <li>Review Cx Plan, provide comments to Commissioning Authority</li> <li>Attend pre-bid meeting</li> <li>Complete designer checklists</li> </ul>

## Appendix E: Issues/Benefit Log Value Report

There are many benefits to adopting the Commissioning Process, such as improved accessibility to equipment, improved documentation, operator training, and generally raising the quality bar for the Owner's project. While many of the benefits are intangible as far as assigning a cost benefit, some can reasonably have dollar benefits attached. Where possible, we try to assign a dollar value to emphasize the savings that are a direct result of the Commissioning Process.

Commissioning Process Fee	\$ 87,319	
Commissioning Process Saved	\$ 1,000	First Cost Savings
	\$97,430	Future Repair Savings
	\$19,415/yr	Operational Cost Savings
	\$ 3,060 /yr	Maintenance Cost Savings

### (Details of some of the savings)

- Alignment, Belt Tensioning, Motor Anchoring Adjustments per Vibration Report.  
**Saved \$2,400 in future repair costs**
- Motor Bearing Noise in 125 HP Supply Fan  
**Saved \$1,000 in first cost of construction**
- Chronic Splashing of Evaporative Cooling Cell Deck  
**Saved \$1,200 in future repair costs**
- Fixing Make-Shift Door Handle Strikes  
**Saved \$800 in future repair costs**
- Marking VAV Box Locations on Ceiling Tile Grid Using Colored Dots  
**Saved \$660 per year in maintenance costs**
- Align Pump Couplings  
**Saved \$3,500 in future repair costs**
- Cavitating Control Valve  
**Saved \$1,500 in future repair costs**
- Separable Sections for Insulated Pump Boxes  
**Saved \$2,080 in future repair costs**
- Grouting Pump Bases  
**Saved \$500 in future repair costs**
- Unions at Control Valves, and Replacement of Low Quality Valves  
**Saved \$1,300 in future repair costs**
- Access Doors for VAV Boxes Over Rigid Ceilings  
**Saved \$1,200 per year in maintenance cost**
- Dielectric Fittings at Heating Coils  
**Saved \$10,000 in future repairs**

13. Conduits Too Full at Control Panels  
**Saved \$450 in future repairs**
14. Backflow Preventers Without Unions or Indirect Waste Funnels  
**Saved \$700 in future repair costs**
15. Stanchion Support for Piping at Large Pumps  
**Saved \$10,500 in future repair costs**
16. Testing Revealed Defective High Duct Pressure Safety Control Circuit.  
**Saved \$20,000 in future repair costs**
17. Testing Revealed Defective Ventilation Damper Linkage.  
**Saved \$18,200 per year in operating costs**
18. Testing Revealed Opportunity for System Efficiency Improved by Modifying Enthalpy Control Setpoints.  
**Saved \$1,215 per year in operating costs**
19. Testing Revealed Opportunity for Reducing IAQ Problems by Modifying Evaporative Cooling Control to drain Down Each Day.  
**Saved \$42,500 in future costs**

## Appendix F: Basis of Design Sample

### CUSD Administrative Facility Basis of Design

#### ***Overview of Basis of Design***

The Basis of Design is created to document the reasoning and assumptions made during the design process. While the Project Intent was limited to non-technical language so that it could be understood by all parties involved in the design process, the Basis of Design includes technical language to document the thought process used by the designers while developing the systems for the building. The Basis of Design details the following:

- Selection of components
- Assumptions made by designer
- Codes and standards used

This information is critical to ensure the contractor, operator, and future designers understand the assumptions made and the limitations of the systems. Without this information, one has to guess at the designers' line of reasoning during their design process. Throughout the design process, the Basis of Design needs to be consistent with the Project Intent. Each Project Intent item must be addressed in the Basis of Design to show how the designer transformed the Project Intent into reality.

#### **Selection of Components**

A short narrative for each type of equipment/component (air handler, terminal boxes, pumps, boilers, chillers, windows, walls, etc.) should include the reasoning for selecting it. Items relating to the Project Intent, such as maintenance requirements, should also be included. In addition, information on the type of equipment selected, specific manufacturer chosen, specific model chosen, or equipment sizing, etc. is included. The reasoning for the selection of components are shown in Table 3.

**Table 3: Reasoning For Selection of Equipment**

Item	Equipment Type	Reason Selected
1	Chillers	Owner requested that the project utilize hermetic centrifugal chillers with full load efficiency of 0.52 kW/ton as manufactured by XXXX. The initial installation will be for a single 300-ton chiller with space for a future 100-ton chiller. A chiller factory performance test has been specified at the request of the Owner.
2	Cooling towers	The cooling towers are induced-draft, counter-flow type with vertical discharge. Tower construction shall be galvanized steel casings, stainless steel cold water basins, and pvc fill. Towers will be provided with service platforms, davits and jib booms for service and replacement of fan motors. Because of cooling tower well height constraints, XXXX is the Basis of Design. No other cooling towers will be acceptable.
3	HVAC pumps	Vertical inline centrifugal pumps are provided at the request of the Owner. These pumps are selected to conserve space in the Mechanical Room without reducing the ability to access and maintain the pumps. Pumps are arranged in a line with hoist beams located directly above the motors to facilitate removal and replacement.

Item	Equipment Type	Reason Selected
4	Boilers	The Owner requested that the project utilize condensing type boilers to conserve space in the Mechanical Room without reducing the ability to access and maintain the equipment.
5	Air handling units	The air handling units are custom manufactured type, complete with fans, motors, cooling coils, heating coils, energy recovery coils, filters, sound attenuators, and accessories housed in a finished solid double-wall casing with thermal insulation. Two plug type fans with isolation dampers are provided in each unit such that failure of one fan will not result in a total failure of the unit. Two cooling coils are provided in each unit to limit the total depth of any one coil to a maximum of 6 rows. This will allow proper cleaning of cooling coils. Energy recovery coils are designed for glycol/water mixture. At the request of the Owner, air handling unit manufacturers are limited to the following: XXXX, YYYY, or ZZZZ.
6	Sound attenuators	Sound attenuators are provided in the general exhaust duct mains to reduce noise in the occupied spaces of the building. Sound attenuators are either packless reactive type or encapsulated type to assure that no glass fibers can enter the systems.
7	VAV supply terminals	At the request of the Owner, terminal unit manufacturers are limited to the following: XXXX, YYYY, or ZZZZ.
8	VSDs	Variable speed drives are provided with integral manual bypasses to allow repair or replacement of the drive without shutting down power to the driven motors. At the request of the Owner, variable speed drive manufacturers are limited to the following: XXXX, YYYY, or ZZZZ.
9	Energy recovery units	The energy recovery units are of the molecular sieve technology, complete with fans, motors, enthalpy wheel, filters, and accessories housed in a finished solid double-wall casing with thermal insulation. At the request of the Owner, energy recovery unit manufacturers are limited to the following: XXXX, YYYY, or ZZZZ.
10	Toilet exhaust fans	Two toilet exhaust systems serve the rest rooms and janitor closets. Exhaust discharge locations are located on the roof of the south stair tower and on the penthouse roof. The toilet exhaust systems are in operation at all times.
11	Unit heaters	Unit heaters will be provided in the stairwells and in the ground floor entry vestibule. Unit heaters will be wall-mounted electric type.
12	Fan coil units	Fan coil units provide cooling and heating for the main mechanical room and the penthouse. Cooling only fan coil units serve the elevator rooms located on the ground floor and in the penthouse. Fan coil units are thermostatically controlled.
13	Control system	The Owner requested that control manufacturers be limited to XXXX and YYYY – the two district-wide control vendors.
14	Ductwork	The ductwork is standard galvanized steel with the following exception: 1. 2 feet between the primary ductwork and VAV terminal units. 2. 5 feet between the supply ductwork and a diffuser.
15	Chilled water piping	Piping is 2-1/2" and larger is welded schedule 40 black steel (Contractor has option to utilize grooved piping, except in concealed chases). Piping 2" and smaller is Type L copper tubing. Underground piping is ductile iron with mechanical joints and joint restraints.
16	Hot water piping	Piping 2-1/2" and larger is welded schedule 40 black steel (Contractor has option to utilize grooved piping, except in concealed chases). Piping 2" and smaller is Type L copper tubing.

### Assumptions Made By Designer

This section of the Basis of Design documents specific numbers used in the design of the building. These assumptions are an essential part of making the transition from the Project Intent to installed equipment. The following are the assumptions made in the Basis of Design. The assumptions made during the design of the CUSD Administrative Facility are shown in Table 4.

**Table 4: Assumptions Made by the Designer**

Item	Description of Assumption	Value (units)
1	Latitude/Longitude	35°52'N / 118°47'W
2	Elevation (1 <sup>st</sup> floor finished floor elevation)	396.52 ft.
3	Clearness number	0.95
4	Summer outdoor air design dry bulb/wet bulb	94°F DB / 65°F WB
5	Winter outdoor air design dry bulb	16°F DB
6	Ground reflectance	0.20
7	Room setpoints, summer / winter  General offices Electrical rooms Mechanical rooms Communication rooms Elevator mechanical rooms	75°F 50%RH / 72°F 90°F / 50°F 90°F / 50°F 80°F / 60°F 90°F / 50°F
8	Roof U-value	0.08
9	Roof construction type	G
10	ASHRAE 90 analysis Overall roof U-value Overall wall U-value Overall building U-value	0.060 0.189 0.128
11	Glass U-value (summer/winter)	0.55 (Design based on XXXX Model 2010A))
12	Glass shading coefficient	0.51
13	People sensible/latent heat generation, Btu/hr	250(sen) / 200(lat)
14	Lighting usage	2 W/sq ft
15	Outdoor air ventilation rate	20% fresh air
16	Infiltration rate	1 cfm/ft <sup>2</sup>
17	Supply air temperature	55°F summer 50°F winter just after heating coil
18	Economizer high limit dry bulb switch over point	68°F
19	Duct heat gain accounted for	0.5°F
20	Duct leakage accounted for	5%
21	Maximum duct noise level/ceiling effect	40 dB
22	90° elbow included after discharge from AHU	Yes
23	Air distribution system diversity	20%
24	Cooling entering/leaving water temperature	45°F / 59°F
25	Cooling entering air temperature	94°F DB 65°F WB
26	Cooling leaving air temperature	52.3°F DB 51.9°F WB
27	Heating hot water entering / leaving water temperature	180°F / 160°F
28	Heating entering / leaving air temperature	0°F DB, 51°F DB
29	Cooling tower condenser water entering / leaving temperature	95°F / 85°F
30	Cooling tower entering air wet bulb temperature	78°F WB
31	Building system peak cooling load (hour ___ of ___ month)	3PM September
32	Design system peak cooling load	290 tons
33	Number of occupants at peak load	192
34	Cooling loads not included	Stairwell cooling loads
35	Fan heat gain accounted for	220,000 BTU/hr
36	Cooling/heating load design program	XXX XXX-X
37	Ductwork sizing program	None
38	Air handling unit selection program	None
39	Minimum chiller efficiency	0.52 kW/ton at peak load 0.42 kW/ton NPLV
40	Expected utility costs	

## Codes and Standards Used

This section of the Basis of Design details the codes and standards that were followed when designing the system. In some cases, systems were designed to “Best Practice”, which often exceeds requirements of codes/standards. The codes and standards that were used in the design of the CUSD Administrative Facility are shown in Table 5.

**Table 5: Codes and Standards Used**

<b>Type</b>	<b>Name of Code/Standard</b>	<b>Why Used</b>
Professional	ASHRAE Standard 52.1-1992 ASHRAE Standard 15-1994 ASHRAE Standard 55-1992 ASHRAE Standard 62-1999 ASHRAE Standard 110-1995	Filter efficiency and arrestance Mechanical refrigeration safety Comfort criteria Ventilation and Indoor air quality Fume hood performance
	NFPA 90A-1996 NFPA 10-1998 NFPA 13-1996 NFPA 14-1996 NFPA 20-1996 NFPA 24-1995 NFPA 45-1996 NFPA 54-1996 NFPA 70-1999	Required, fire protection
	Standard Fire Prevention Code-1997	
	ANSI/CABO A117.1-1998	Plumbing systems
	ADA-1990	Required for accessibility
	ARI 550/590-1998	Factory performance test of one of the chillers
	SMACNA Duct Construction Standards-1995	Standard practice for duct construction
State	California State Building Code 2000	Required
Local		
Owner's Criteria		

## Appendix G: Design Review Procedure

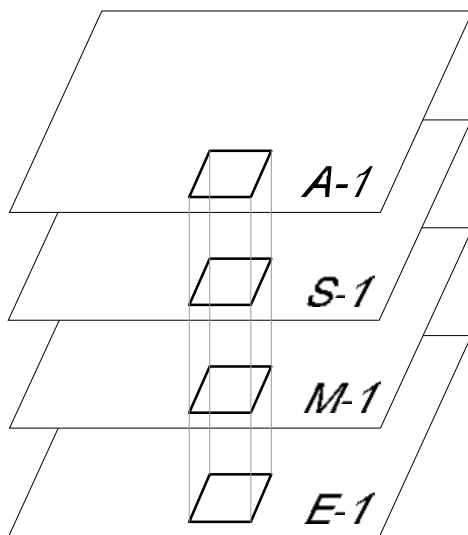
A critical step in the Commissioning Process is the review of the drawings from the design professionals. It is important to remember that the role of the Commissioning Authority is to verify that the Owner's Project Intent is achieved and that the system is designed in a quality manner. There are three distinct reviews that are completed on a drawing set – general, coordination and field specific. A review of the specifications is also required. The general steps of completing a drawing review are:

### General Review

1. Review the Project Intent – since the drawing review is to verify the Owner's Project Intent is achieved, prior to the review, the Project Intent should be reviewed to familiarize the reviewer with the key criteria of the building.
2. Document the General Review Criteria – the criteria from which to accomplish the general review of the drawings must be documented. The criteria should be based on general quality characteristics and specific Project Intent criteria. The general quality characteristics should include items such as:
  - Continuation of items (ductwork, pipes, etc.) from page to page
  - Labeling, including correct room numbering
  - Details corresponding to actual components
  - Schedules include basis of design information
  - All information is legible (not hidden by crossing lines or text)
  - Project Intent information is included on drawings
3. Accomplish Quick General Review – the general review is intended to familiarize the reviewer with the drawings. If during this review significant items are identified as poor quality, then the review process should be stopped and the A/E contacted to discuss the quality concerns. If the general quality is good, move onto the Coordination Review.

### Coordination Review

1. Determine Sampling Areas – for each floor plan area (i.e.: if there are five sheets for each floor, then there are five floor plan areas for each floor) select a single 10" by 10" square randomly. A simple way to do this is to divide the drawing sheet into 15 squares (5 by 3) and select square number 3 on the first sheet (area) and then 5, 7, etc. for each remaining area. This selection is accomplished typically using the architectural sheets.

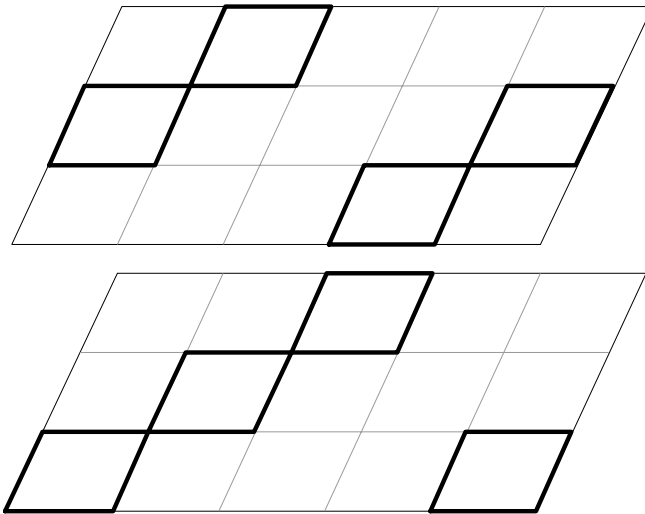


2. Select review Samples on Drawings – using the sampling strategy chosen in Step 1, mark the sample areas to be reviewed in each area. This should be accomplished for each trade (landscaping, architectural, structural, plumbing, mechanical, electrical, etc.).
3. Accomplish Coordination Review – for each area, compare the squares between each drawing sheet. The intent of this review is to identify coordination problems with the placement and installation of components. Items of specific interest include:
  - Placement of multiple pieces of equipment/components in the same location
  - Accessibility to equipment/components for maintenance/replacement
  - Use of consistent terminology (i.e.: room numbers, etc.)
  - Elevations provided where multiple systems are placed in the same area
  - Other trade duties clearly identified (i.e.: electric wiring for HVAC equipment, holes for sinks, etc.)

If significant coordination problems are identified, stop the review and contact the A/E to discuss. If the coordination is good, continue on with the Field Specific Review.

### **Field Specific Review**

1. Determine the Review Sampling Procedure – the sampling procedure needs to be based on statistical techniques to obtain a general sampling of the drawings is obtained for review purposes. Essentially, the key to obtain good results is to use random rational sampling. The sampling frequency randomly selects every  $x^{\text{th}}$  square on the drawings to be verified. Squares that are completely blank (no walls, equipment, etc.) are not included in the counting. For example, if there are 10 pages of drawings and each drawing is split into 15 grids (5 x 3), there will be 150 potential grids to review. If a 20% sample rate is desired, then 30 grids would be reviewed, or every 5 grids. The starting grid should be chosen using a random selection process (use a die, choose a card [numbered 1-6] from a hat, etc.).



2. Record Drawing Review Criteria – the criteria from which to review the drawings should be based on specific Project Intent criteria. This should include items such as accessibility, maintainability, meeting of specifications, comfort conditions, documentation of Project Intent and basis of design, and operating details.
3. Select Review Samples on Drawings – using the sampling strategy chosen in Step 1, mark the sample areas to be reviewed.

4. Accomplish Detailed Statistical Review – using the review criteria from Step 2 and the selections from Step 3, accomplish a detailed review of the drawings. This includes verifying that the specifications match the drawings (see below for specification review details).
5. Document Concerns – during the review of the drawings keep detailed notes of problems found or concerns with certain items. Also, at the end of the review, a general summary of the quality of the drawings should be developed. A letter detailing the quality of the drawings should then be sent to the A/E and the owner with specific recommendations and directions given.

### ***Specification Review***

1. Determine the Review Sampling Procedure – the purpose of this review is to determine the general quality of the specifications. During the Field Specific Review the actual details are checked. The sampling procedure should check approximately 10% of the specifications. The easiest way of doing this is to check every x<sup>th</sup> page of the specifications (i.e.: if there are 100 pages, check every 10<sup>th</sup> page).
2. Accomplish General Review – the review should focus on the quality of the specification, specifically:
  - Are there excess sections that do not pertain to the project (i.e.: medical gas in an office building, 15 types of valves when only 2 used, etc.)?
  - If a manufacturer has been listed, has the engineer checked to verify the Project Intent is met?
  - There are no “or as equals”
  - Basis of Design is clearly stated
  - The directions are clear and concise
3. Develop Summary of Review – develop a summary of the review. If there are problems with the specifications, contact the A/E and discuss.
4. Review the Design Review Procedure – after the drawing review is completed, this document should be reviewed and modified to improve the process for the next time.

## Appendix H: System Manual Scope of Work

### General Provisions

- A. CLIENT requires that the operations and maintenance (O&M) manuals be submitted in electronic format in accordance with the structure and content described within this specification. Contractors shall complete and submit three copies of each O&M manual section (section is defined as individual component package) **within two months** of the respective submittal acceptance. These will be reviewed by the Commissioning Authority, the Owner's Project Manager (PM), and the Architect and Engineer (A/E).
- B. The initial draft of the O&M manual must be available for review **ninety (90) days** prior to scheduled training. The final O&M manual must be available **sixty (60) days** prior to the original substantial completion date. The General Contractor shall compile the final O&M manual and submit **10 complete copies** to the owner's representative.
- C. The O&M manuals are to cover ALL systems and components within the facility as defined by these specifications. This includes, but is not limited to all mechanical, electrical, controls, fire alarm, fire protection, security, architectural, communications, and audio/visual systems and components.
- D. The final O&M manuals must be revised after the last changes to the systems and components to reflect these changes.
- E. Final O&M manuals shall be submitted in a format that allows the owner and his or her agents to modify, expand, add, eliminate, and/or edit any information, documentation, or materials within the O&M manual as deemed necessary by these parties. This requirement shall include sufficient training and software for owner's agents necessary to train and equip the designated persons for this task.
- F. O&M manuals are NOT to be submitted in paper format. However, any O&M manual submitted must allow users to print any portion of the manual on to a standard size medias of 8 ½" x 11", 8 ½" x 14", or 11" x 17".
- G. Acceptable electronic formats for O&M manuals include Word 97 or newer, WordPerfect version 8.0 or newer, Adobe Acrobat 4.0 or newer, or some web based format. Other formats may be acceptable, but must be pre-approved. Contractors are responsible to ensure users are equipped with appropriate software and/or viewers for the O&M manual. This includes any additional software and/or viewers necessary for as built and shop drawings.
- H. Documentation contained within the O&M manual must be annotated and edited to reflect only that information pertinent to the component or system it is to describe. Scanned information is acceptable but also must meet these criteria.
- I. O&M manual shall be fully searchable. This is to mean that users shall be able to search the entire contents of manual using simple text search functions.
- J. The O&M manuals shall be fully integrated and navigable. "Fully integrated and navigable", is defined in this context as the ability for users to review and locate information for a particular component via location of, system connected to, or actual definition of a component. In addition, it also implies that the user may also be able to locate and link to all pertinent information for a component from a single source.
- K. Commissioning Authority Review and Approval: Prior to substantial completion, the Commissioning Authority shall review the O&M manuals for compliance to this specification. The Commissioning Authority will communicate deficiencies in the manuals to the PM and A/E. Upon successful review of the corrections, the Commissioning Authority shall recommend approval and acceptance of the O&M manual sections to the PM. This work does not supersede the A/E's review of the O&M manuals according to the A/E's contract.

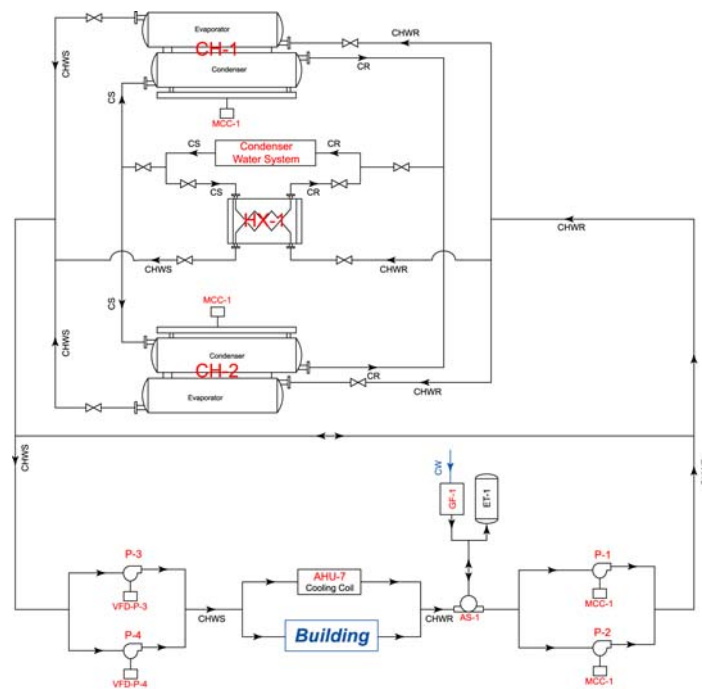
## **Structural/Content Provisions**

- A. O&M manuals shall consist of five divisions: general information, facility information, system definitions, component information, and system troubleshooting procedures. The following sections define the structure, order, and content of these divisions.

1. General Information: The general information division of the manual shall consist of the pages defined below.
  - a. Title/Home Page: A title/home page shall be included with the O&M manual. This page shall act as the beginning point for the manual and will include the following information and links:
    - i. General description of the manual and its contents. Including general guidance on the use and navigation of the manual.
    - ii. Links to all other general information pages.
    - iii. A list or link to a listing of all defined rooms.
    - iv. Listing and links to all systems defined within the manual.
    - v. A list or link to a listing of all available components defined within the manual.
  - b. Table of Contents: A table of contents is required for the manual. This table of contents must list and link to all information contained within the manual, including all manufacturer provided documentation.
  - c. Contact Listing: A listing of all contractors, sub-contractors, architects, and engineers involved with the project. This listing shall be sorted alphabetically by company and include the following information for each contact:
    - i. Company
    - ii. Contact Person
    - iii. Address
    - iv. Phone Number
    - v. Fax Number
    - vi. Emergency Phone Number
    - vii. E-mail address (if available)
    - viii. Web Address (if available)
    - ix. Project role and responsibilities
  - d. Vendor Listing: A listing of all suppliers involved with the project. This listing shall be sorted alphabetically by company and include the following information for each contact:
    - i. Company
    - ii. Contact Person
    - iii. Address
    - iv. Phone Number
    - v. Fax Number
    - vi. Emergency Phone Number
    - vii. E-mail address (if available)
    - viii. Web Address (if available)
    - ix. Equipment/components supplied
  - e. Manufacturer Reference Listing: A listing of all manufacturers involved with the project. This listing shall be sorted alphabetically by company and include the following information for each contact:
    - i. Company
    - ii. Contact Person
    - iii. Address
    - iv. Phone Number
    - v. Fax Number
    - vi. Emergency Phone Number
    - vii. E-mail address (if available)
    - viii. Web Address (if available)
    - ix. Equipment/components supplied

- f. Commissioning Record and Testing Data: This is a separate manual provided by the Commissioning authority dedicated to the documentation of the commissioning process utilized for the project. This includes all certifications, plans, testing data, procedures, reports, etc.
  - g. LEED Certification Documentation: This is a separate manual provided by the Owner or another entity designated by the Owner. This manual is intended to document all information and materials used or submitted for the certification of the project according the LEED certification program.
2. Facility Information: Facility information includes a definition and breakdown of the facility into a logical organizational and informational structure. This division includes the following information:
- a. Facility Definition: The facility definition shall be the initial information or title page for this division. This page is to relay general information regarding this facility and provide the following links and information on the page:
    - i. Facility Photograph: A photograph of the entire facility.
    - ii. Facility Description: An overall description of the facility, including information such as the overall use, total square footage, etc.
    - iii. Systems List: A list or link to a listing of all systems encompassed or serving the facility. All items defined within this listing should be linked directly to the system defined.
    - iv. Component List: A list or link to a listing of all components within the facility. All items defined within this listing should be linked directly to the component defined.
    - v. Floor Plan Listing: A list or link to a listing of all floor plans defined within this facility. All items defined within this listing should be linked directly to the floor plan defined.
    - vi. Room List: A list or link to a listing of all rooms within the facility. All items defined within this listing should be linked directly to the room defined.
  - b. Floor Plan Definition: The floor plan definition shall describe and link all information available for each floor within the facility. Each floor shall have a sheet defined which includes the following information and links:
    - i. Floor Plan: A graphic depicting the overall layout of the floor, including all room numbers.
    - ii. Floor Description: An overall description of the floor, including information such as the overall use, total square footage, etc.
    - iii. Systems List: A list or link to a listing of all systems encompassed or serving the floor. All items defined within this listing should be linked directly to the system defined.
    - iv. Component List: A list or link to a listing of all components within the floor. All items defined within this listing should be linked directly to the component defined.
    - v. Room List: A list or link to a listing of all rooms within the floor. All items defined within this listing should be linked directly to the room defined.
  - c. Room Definition: The room definition shall describe and link all information available for each room within the facility. Each room shall have a sheet defined which includes the following information and links:
    - i. Room Description: A overall description of the floor, including information such as the overall use, total square footage, person responsible for room, designed occupancy, time of use schedules, etc.
    - ii. Exterior Wall Definitions: The exterior wall definitions will document all available information regarding the type, area, and composition of all exterior walls within a room. This includes links to any available information for wall materials, definition of finishes and/or coverings and their respective instructions for care, links to detail diagrams, gross area for each type defined, etc.
    - iii. Interior Wall Definitions: The interior wall definitions will document all available information regarding the type, area, and composition of all interior walls within a room. This includes links to any available information for wall materials, definition of finishes and/or coverings and their respective instructions for care, links to detail diagrams, gross area for each type defined, etc.
    - iv. Floor Definitions: The floor definitions will document all available information regarding the type, area, and coverings for all flooring within a room. This includes links to any available information for materials, definition of finishes and/or coverings and their

- respective instructions for care, links to detail diagrams, gross area for each type defined, etc.
- v. **Ceiling Definitions:** The ceiling definitions will document all available information regarding the type, area, and composition of all ceilings within a room. This includes links to any available information for materials, definition of finishes and/or coverings and their respective instructions for care, links to detail diagrams, gross area for each type defined, etc.
  - vi. **Window Definitions:** The window definitions will document all available information regarding the type, area, and number of all windows within a room. This includes links to manufacturer information, definition of finishes and/or coverings and their respective instructions for care, links to detail diagrams, gross area for each window type defined, etc.
  - vii. **Door Definitions:** The door definitions will document all available information regarding the type, area, and number of all doors within a room. This includes links to manufacturer information, definition of finishes and/or coverings and their respective instructions for care, links to detail diagrams, gross area for each door type defined, list of all hardware utilized for each door type and links to its respective information, etc.
  - viii. **Systems List:** A list or link to a listing of all systems encompassed or serving the room. All items defined within this listing should be linked directly to the system defined.
  - ix. **Component List:** A list or link to a listing of all components within the room. All items defined within this listing should be linked directly to the component defined.
3. **System Definitions:** System definitions include a description and graphical representation of the purpose and composition of all systems as detailed within the general provisions section of this specification. For each of these systems listed one sheet shall be developed containing the following information and links:
- a. **System Ladder Diagram:** Each system sheet shall include an engineering ladder diagram that is representative of the system. This graphic shall show all components and respective tags that are contained within the system, all interfaces with other systems, all destination or service areas, and visualization of flow direction. Crossover of lines should be avoided if possible. The following figure is an example of such a diagram.



**Figure 9: Example System Ladder Diagram**

- b. System Description: Each system sheet shall include a description of the system and its function within the facility. This description shall include general information on the normal operating conditions of the system at the time of final testing and balancing.
  - c. System Procedures: A set of links to documents containing detailed procedures for start-up, shutdown, emergency, seasonal changeover, and manual operation.
  - d. Component List: A list or link to a listing of all components associated directly with system defined. This list should represent all items shown within the system ladder diagram, and all items defined within this listing should be linked directly to the component defined.
  - e. System Troubleshooting Procedures: Link to a documentation describing the troubleshooting procedures for evaluation of the system as a whole. This document is to be developed by the Contractor and is described further in a later section of this specification.
  - f. For the control system ONLY, the following additional information shall be present:
    - i. A list of links to control system training materials.
    - ii. A list or link to a listing of all available control system record drawings, including all sequence of operations and logic diagrams for all components.
    - iii. A link to a full point list describing the following information for each room in tabular format:
      - 1. Location: Building, floor, and room number.
      - 2. AHU Tag #
      - 3. Reference Drawing #
      - 4. Air terminal unit Tag #
      - 5. Heating and/or cooling Tag #
      - 6. Minimum/Maximum cfm
      - 7. Room set points and range
    - iv. Link to a listing of all component and room set points and ranges.
    - v. Link to copy of entire control software program.
    - vi. Link to control software interface.
    - vii. List or link to listing of documentation on all checkout tests and calibrations performed.
4. Component Information: The component information shall consist of individual sheets defined for each component present within the facility. These sheets shall include the following information and links:
- a. Title: The title shall clearly define the component type and tag of the component described by the sheet.
  - b. General Information: The general information section shall clearly define the following information in a tabular format in the order defined below:
    - i. Tag Number
    - ii. Manufacturer
    - iii. Model
    - iv. Serial Number
    - v. Location: Building, floor, and room number.
    - vi. Contractors Information: A listing of contact information for all contractors responsible for the installation, wiring, and TAB of a component. This item may also be a link to the particular information.
  - c. Component Photograph: Photograph of unit in final installed location and orientation.
  - d. Performance Characteristics: A table containing design, submittal, and installed performance characteristics of a component in similar structure and content as that defined by the record drawings schedules.
  - e. Safety Precautions: Link to a document containing personnel hazards and component safety precautions for components under all operating conditions.
  - f. Operation Procedures: List or link to a listing of documents containing detailed procedures for start-up, shutdown, emergency operation. The items defined within this listing shall be directly linked to the document defined.
  - g. Documentation: List or link to a listing of all available documentation for a component. The following is a list of documentation required for each component as available:
    - i. Relevant Specification section
    - ii. Submittal
    - iii. Engineering Guide

- iv. Installation, Operation, and Maintenance Manuals
- v. Parts List: The parts list shall be composed of documentation that conveys the following information:
  - 1. Exploded Component Diagram: Diagram that clearly shows and labels all parts of the component.
  - 2. Identification table of parts shown in illustration with following additional information in tabular format:
    - a. Part Number
    - b. Manufacturer
    - c. Model
    - d. Serial Number
    - e. Catalog Number
    - f. Vendor Information: Contact information for available vendor of a defined part. This information may supplied as a link, and must contain the following information:
      - i. Company
      - ii. Address
      - iii. Phone Number
      - iv. Fax Number
      - v. E-mail and web address (if available)
- vi. Troubleshooting Procedures: Link to available manufacturer troubleshooting procedures.
- vii. Preventative Maintenance Procedures: The preventative maintenance procedures shall include both documentation from the manufacturer on required maintenance, and documentation developed by the Contractor that describes the following information:
  - 1. Documentation in checklist form that describes the preventative maintenance requirements of a component according to recurrence of procedures. (Daily, monthly, bi-annually, etc.). This documentation will include all lubrication requirements and instructions. A separate document shall be developed for each level of recurrence.
  - 2. Each checklist shall include information and links to information on how to perform each task, the tools required, and safety precautions.
- viii. Record Drawings: A link, or links, to all relevant record drawings.
- ix. Detail Diagrams and Shop Drawings
- x. Performance Data, Ratings, and Curves: Documentation describing performance characteristics of a component at a minimum of five (5) part load conditions for all normal operating conditions.
- xi. Controls Documentation: A list or link to a listing of documentation containing information on the control logic diagrams, sequence of operation, control set points, and calibration tests for a component. This list shall also include a calibration schedule defining the re-calibration requirements for a component, if applicable.
- xii. Testing and Balancing Documentation: Link to applicable section of TAB report for a component.
- xiii. Warranty Information: A set of links to the following warranty documentation shall be included:
  - 1. Copy of the warranty
  - 2. Listing and explanation of the warranty terms and conditions.
  - 3. Date of warranty expiration.
- xiv. Training Documentation: A list or link to a listing of all training materials available for a component. This shall include, but is not limited to the following information:
  - 1. Copy of any and all training seminars conducted and taped.
  - 2. Copy of all associated training materials distributed during training seminars.
- xv. Tool Requirements: A link to documentation defining the tools required by Owner personnel to perform testing, calibration, operation, maintenance, and repair on a component.
- xvi. Systems List: A list or link to a listing of all systems the component is associated with. All items defined within this listing should be linked directly to the system defined.



# Appendix I: Example Functional Performance Test Structure

## Overview

One of the final steps in the commissioning process is conducting a functional performance test. The purpose of the functional performance test is to ensure that the building systems meet the requirements of the owner's project intent. It is assumed that all equipment verification and controls verification testing has been performed and accepted before the functional performance tests are conducted. Therefore, if the commissioning process was followed throughout the planning, design, and construction of the building, the functional performance test should be easily accomplished and not require major corrections or re-work to the building or building systems.

Parties that should be included in the functional performance test include: owner or owner's representative, commissioning authority, mechanical contractor, controls contractor, and building maintenance staff.

## Pre-Requisites

Prior to Functional Performance Testing, all equipment under the command of the control system must be installed, started up, and verified. Additionally, the Testing and Balancing of said equipment must be complete and verified. Before beginning these tests, the control system to be verified must be installed, calibrated, and pre-tested by the contractor for proper operations. Random sampling will be used to conduct the Functional Performance Tests. Many or all of the functions associated with larger mechanical systems will be verified, but only representative samples of smaller, unitary, and more repetitious systems will be verified.

## Project Intent Goals

The project intent goals to be evaluated by functional performance testing are:

- Temperature: Must be individually controlled for each room to maintain 76°F during peak summer conditions and 72°F during peak winter conditions. The temperature between spaces that have thermostats set at the same temperature shall vary by less than 2°F. The room temperature will be adjustable by room occupants within a  $\pm 2^\circ\text{F}$  range of the winter and summer set-points of 72°F and 76°F, respectively.
- Relative humidity: The relative humidity within the occupied space shall not exceed 50% during summer operation when the building is occupied. No minimum limit is required during winter operation.
- Indoor air quality: Pollutants generated in the space shall be exhausted to the outdoors and not returned to the central air handling unit. The definition of pollutants includes, but is not limited to food odors, bathroom odors, art supplies, science labs, project materials, building materials, and exterior exhaust odors. There shall be no transfer of odors between spaces. The carbon dioxide (CO<sub>2</sub>) differential between indoors and outdoors shall not exceed 700 ppm.
- Air distribution: There shall be uniform air distribution (defined as diffusers selected to meet an ADPI rating of at least 80%) with no noticeable drafts, stagnant areas, or stratification throughout the building.
- Noise level: The noise level in the classrooms and offices without any people should be less than 35 RC. The noise level in the hallways, cafeteria, and gymnasium shall be less than 45 RC. (*HVAC Applications Handbook*, ASHRAE, 1999, p. 46.25)
- Lighting level: The lighting levels throughout the building should be appropriate for the tasks conducted in the room. Classrooms, particularly the front of the room by the chalkboard, are especially important to be properly lit to ensure that lighting levels do not negatively impact learning.

Each of these project intent goals will either be evaluated by measuring actual values (whenever possible) or by observing the conditions in the building and providing a qualitative evaluation.

## Trend Data

Trend data should be obtained for the duration of the Functional Performance Test period to verify the system response. The time when each test is performed should be recorded so that the results can be correlated to the trended data. Where possible, the points associated with each test should be grouped together in a single trend report using a composite axis, so that the interrelated data is readily apparent and so the trend output can be attached to the test procedure results.

In general, data should be trended approximately every 15 seconds to identify control system stability and tuning problems (hunting). Alternately, trend point logging by change of state (discrete points) and threshold change (analog points) may be utilized provided the thresholds are suitably close to produce meaningful results. Trending method used, point groupings, etc. should be coordinated between the control contractor and the commissioning authority prior to testing.

Where controlled device position is to be trended, it may be actual measured position, if available, or may be implied position using the controller's output value as the implied position. The units should be 0-100% open. Where VFD motor speed is to be trended, it may be actual measured speed, if available, or may be implied speed using the controller's output value as the implied position. The measurement units should be 0-100% speed if possible, not hertz, so that it can be more easily correlated to the controller output which is 0-100%.

Stability of controls is addressed in most of the procedures that follow. The graphical trend feature of the control system software is very useful in verifying this. Stability of each control loop is determined by comparing its setpoint to its measured value, after a step change, and seeing the error decay after just a few cycles above and below the steady state line. Continued oscillation about the setpoint is indicative of a tuning problem and should be addressed even if minor in nature, because this condition can shorten the controlled device life span by wearing it out from continuous movement.

The following trend data should be recorded for the duration of functional performance testing:

### Hot Water System

Boiler status (each boiler)  
HWS and HWR temperature and setpoint  
House / secondary HW pump VFD %

### AHU's

Fan status  
OA, SA, RA, and MA temperatures  
SA temperature setpoint  
VFD %  
HW and CW valve position  
OA and RA damper positions

### Chilled Water System

Chiller status (both chillers)  
CWS and CWR temperature and setpoint  
House / secondary CW pump VFD %

### VAV Boxes / Fan Coil Units

Fan status  
Space temperature and setpoint  
HW valve position (and CW valve position for FCU)  
Inlet damper position (VAV box only)  
Airflow value and setpoint (VAV box only)

## Abbreviations

SA	Supply Air	VFD	Variable Frequency Drive
RA	Return Air	SP	Static Pressure
MA	Mixed Air	S/S	Start-Stop
OA	Outside Air	Min	Minimum
XA	Exhaust Air	Max	Maximum
SAT	Supply Air Temperature	RH	Relative Humidity
RAT	Return Air Temperature	°F	Temperature, Degrees Fahrenheit
MAT	Mixed Air Temperature	In. w.c.	Pressure, Inches Water Column
CHW	Chilled Water	AFMS	Air Flow Monitoring Station
HW	Heating Hot Water	CFM	Cubic Feet Per Minute
VAV	Variable Air Volume	FPM	Feet Per Minute
AHU	Air Handling Unit	EMS	Energy Management System
FCU	Fan Coil Unit		

## Occupied Cooling Mode – Steady State Test

Date /

Time: \_\_\_\_\_ Test Observed By: \_\_\_\_\_

### Procedure

Perform this test during normal occupied hours or set the control system to occupied mode. In either case, allow the control system to operate for approximately 15 to 30 minutes for the system to stabilize before beginning testing. Make sure doors and windows are closed and there are no other possible interference sources with the HVAC system maintaining normal operating conditions. The control system should not be overridden during this testing except if necessary to place the building in occupied mode (e.g., if the testing is done after normal school hours or on a weekend).

Verify each of the project intent goals by measuring or observing the following:

- Temperature: measure the space temperature near the space temperature sensor ( $76^{\circ}\text{F} \pm 2^{\circ}\text{F}$ )
- Relative humidity: measure the relative humidity ( $< 50\%$ )
- IAQ: measure the  $\text{CO}_2$  level in the room and outside ( $\text{Room} < \text{Outside} + 700 \text{ ppm}$ )
- Noise: note if the noise from the HVAC system is excessive or distracting in the room (observe, describe if high)
- Lighting Level: record the lighting level in foot-candles at the chalkboard (for classrooms) and near the center of the room. Note if there are any dark areas in the room. (50 to 100 foot-candles)
- Air Distribution: walk through several locations in the room and observe if there are any areas of drafts or disruptively high air flow.

In addition, verify that the control system for each room tested is stable by observing the trend logs for the VAV box, fan coil unit, or air handling unit that serves the room. Include trend logs for each room verified in the functional performance test report, and include in the Results table whether the activity on the trend log was acceptable.

Once the test is completed, return the control system to its regular modes of operation (if was overridden).

**This portion of the test will be considered successful if the *Project Intent Goals* are satisfied.**

## Results

Room #	Time	Temperature (°F)	Relative Humidity (%)	CO <sub>2</sub> Level (ppm)	Noise Level OK (Yes / No)	Lighting Level (foot-candles)		Control System Is Stable (Yes / No)	Noticeable Drafts (Yes / No)
						Chalkboard	Room		

<b>Outside CO<sub>2</sub> Reading:</b>	ppm	<b>Allowable Differential:</b>	700 ppm	<b>Acceptable Indoor Level:</b>	ppm
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*General Comments:*

## Occupied Cooling Mode – Step Change Test

Date /

Time: \_\_\_\_\_ Test Observed By: \_\_\_\_\_

### Procedure

This test is to follow the steady state cooling test and is designed to verify control system stability during a step change. With the control system in occupied cooling mode, change the space temperature setpoints for all rooms from the normal setpoint of 76°F to 72°F. With the trend logs recording, wait approximately 30 minutes for the rooms to reach setpoint.

Verify that the space temperature is near the reduced space temperature sensor ( $72^{\circ}\text{F} \pm 2^{\circ}\text{F}$ ). In addition, verify that the control system for each room tested is stable by observing the trend logs for the VAV box, fan coil unit, or air handling unit that serves the room. Include trend logs for each room verified in the functional performance test report, and include in the Results table whether the activity on the trend log was acceptable.

Once the test is completed, return the room cooling setpoint to its normal value.

**This portion of the test will be considered successful if the control system reaches the new setpoint and the control system is stable (does not hunt or overshoot by a large margin).**

### Results

Room #	Time	Temperature (°F)	Control System Is Stable (Yes / No)	Comments

**General Comments:**

## ADPI Test

Date /

Time: \_\_\_\_\_ Test Observed By: \_\_\_\_\_

### Background

For additional details on ADPI testing, see ASHRAE Standard 113-1990.

The ADPI rating is defined as the percentage of readings in a space where the air velocity is less than 70 feet per minute and the effective draft temperature is between  $-3$  and  $2^{\circ}\text{F}$ . The effective draft temperature,  $\theta$ , is defined as:

$$\theta = T_{Local} - T_{RoomAverage} - 0.07 \cdot (V_{Local} - 30),$$

where,

$T_{Local}$  = Local air temperatures at a given point in space,  $^{\circ}\text{F}$

$T_{RoomAverage}$  = Ambient temperature (average room temperature or control temperature,  $^{\circ}\text{F}$ )

$V_{Local}$  = Local air velocity, fpm

### Procedure

Measure the air velocity and calculate the effective draft temperature over a grid pattern from 4" to 5'6" above the floor for two classrooms. The grid pattern shall record the room temperature and air velocity at heights of 4", 24", 42", and 66" from the floor. At least two planes shall be tested in each room, with spacing of 2 to 12', one plane centered on a diffuser and one plane that includes air patterns from two diffusers. A minimum of 5 test positions shall be made along each test plane, with the two end positions for each plane being not closer than 2' from the wall and the others being evenly spaced and not more than 6' apart.

Determine the percentage of points that met the criteria defined under *Background*. The School City of Hammond requires a minimum of an 80% ADPI rating under all flow conditions.

Create a sketch of the room and the test points, which will then be included in the FPT report.

Once the test is completed, return all overridden points, modes and sequences to their original state.

**This portion of the test will be considered successful if an ADPI rating of 80% is achieved.**

## Results

**Room #:**

Plane	Position	Height	Local Temperature (°F)	Local Air Velocity (fpm)	Velocity < 70 fpm?	Reference Temperature (°F)	Effective Draft Temperature (°F)	Effective Draft Temp. Between -3 and 2°F?	Velocity and Temp. Criteria Met?
1	1	4"			Yes / No			Yes / No	Yes / No
1	1	24"			Yes / No			Yes / No	Yes / No
1	1	42"			Yes / No			Yes / No	Yes / No
1	1	66"			Yes / No			Yes / No	Yes / No
1	2	4"			Yes / No			Yes / No	Yes / No
1	2	24"			Yes / No			Yes / No	Yes / No
1	2	42"			Yes / No			Yes / No	Yes / No
1	2	66"			Yes / No			Yes / No	Yes / No
1	3	4"			Yes / No			Yes / No	Yes / No
1	3	24"			Yes / No			Yes / No	Yes / No
1	3	42"			Yes / No			Yes / No	Yes / No
1	3	66"			Yes / No			Yes / No	Yes / No
1	4	4"			Yes / No			Yes / No	Yes / No
1	4	24"			Yes / No			Yes / No	Yes / No
1	4	42"			Yes / No			Yes / No	Yes / No
1	4	66"			Yes / No			Yes / No	Yes / No
1	5	4"			Yes / No			Yes / No	Yes / No
1	5	24"			Yes / No			Yes / No	Yes / No
1	5	42"			Yes / No			Yes / No	Yes / No
1	5	66"			Yes / No			Yes / No	Yes / No
1	1	4"			Yes / No			Yes / No	Yes / No
2	1	24"			Yes / No			Yes / No	Yes / No
2	1	42"			Yes / No			Yes / No	Yes / No
2	1	66"			Yes / No			Yes / No	Yes / No
2	2	4"			Yes / No			Yes / No	Yes / No
2	2	24"			Yes / No			Yes / No	Yes / No
2	2	42"			Yes / No			Yes / No	Yes / No
2	2	66"			Yes / No			Yes / No	Yes / No
2	3	4"			Yes / No			Yes / No	Yes / No
2	3	24"			Yes / No			Yes / No	Yes / No
2	3	42"			Yes / No			Yes / No	Yes / No
2	3	66"			Yes / No			Yes / No	Yes / No
2	4	4"			Yes / No			Yes / No	Yes / No
2	4	24"			Yes / No			Yes / No	Yes / No
2	4	42"			Yes / No			Yes / No	Yes / No
2	4	66"			Yes / No			Yes / No	Yes / No

Plane	Position	Height	Local Temperature (°F)	Local Air Velocity (fpm)	Velocity < 70 fpm?	Reference Temperature (°F)	Effective Draft Temperature (°F)	Effective Draft Temp. Between -3 and 2°F?	Velocity and Temp. Criteria Met?
2	5	4"			Yes / No			Yes / No	Yes / No
2	5	24"			Yes / No			Yes / No	Yes / No
2	5	42"			Yes / No			Yes / No	Yes / No
2	5	66"			Yes / No			Yes / No	Yes / No
3	1	34"			Yes / No			Yes / No	Yes / No
3	1	43"			Yes / No			Yes / No	Yes / No
3	1	66"			Yes / No			Yes / No	Yes / No
3	3	4"			Yes / No			Yes / No	Yes / No
3	3	34"			Yes / No			Yes / No	Yes / No
3	3	43"			Yes / No			Yes / No	Yes / No
3	3	66"			Yes / No			Yes / No	Yes / No
3	3	4"			Yes / No			Yes / No	Yes / No
3	3	34"			Yes / No			Yes / No	Yes / No
3	3	43"			Yes / No			Yes / No	Yes / No
3	3	66"			Yes / No			Yes / No	Yes / No
3	4	4"			Yes / No			Yes / No	Yes / No
3	4	34"			Yes / No			Yes / No	Yes / No
3	4	43"			Yes / No			Yes / No	Yes / No
3	4	66"			Yes / No			Yes / No	Yes / No
3	5	4"			Yes / No			Yes / No	Yes / No
3	5	34"			Yes / No			Yes / No	Yes / No
3	5	43"			Yes / No			Yes / No	Yes / No
3	5	66"			Yes / No			Yes / No	Yes / No

## Appendix J: Division 1 Specification Changes

### 01660 – SYSTEM & EQUIPMENT STARTUP & TESTING

[Insert the following in the appropriate section]

#### 1.1 FUNCTIONAL PERFORMANCE TESTING **EDIT LIST**

A. The systems and assemblies in the building will be tested to verify the facility operates properly as a whole. This testing provides both the owner and contractor with documentation that the building was operating properly at **Project Acceptance**. The specific systems and assemblies to be tested include:

1. Building Envelope
  - a) Wall systems
  - b) Doors
  - c) Windows
  - d) Roofs
2. Transportation Systems
  - a) Elevators
  - b) Escalators
3. Div. 15 Systems (other than controls)
  - a) Domestic Hot Water Generators
  - b) Heating Hot Water Generators
  - c) Space pressurization (throughout VAV range)
  - d) Other System Test (TBD, allow two added tests)
4. HVAC Control System
  - a) Control System Instrument Calibration
  - b) Equipment Safety Shutdown Controls
  - c) VFD Ramp-Up and Ramp-Down Settings
  - d) VAV Outside Air Volume Flow
  - e) Air Side Economizer Control
  - f) Supply-Return Fan Matching Control
  - g) VAV Supply Fan Static Pressure Control
  - h) Plate-Frame to Mechanical Cooling Changeover
  - i) Cooling
  - j) Heating
  - k) Humidity Control
  - l) Heat Recovery Unit Control
  - m) Power Loss / Re-Start
  - n) VAV Box Control
  - o) Other System Test (TBD, allow two added tests)
5. Electrical System
  - a) Lighting Control System
  - b) Emergency Power System
  - c) Daylighting Controls
  - d) Fire Alarm System
  - e) Other System Test (TBD)
6. Other System Test (TBD, allow two added tests)

- B. Each contractor will be responsible to implement the Functional Performance Tests under the oversight of the Commissioning Authority. This includes putting the system in various modes of operation, to fix minor problems found during the test, and to witness the testing. Where a procedure is developed by the Commissioning Authority for the test, the contractor shall implement the test to the satisfaction of the Commissioning Authority.
- C. If major problems are discovered during the test, the responsible contractors will fix the problem and the test shall be redone. If more than two functional performance tests are required, the responsible contractor will be back-charged for the Commissioning Authority's time and expenses.
- D. The Commissioning Authority will provide all commissioning team members, and others as required, the functional performance test plan prior to scheduled testing.
- E. Length of time for the test procedures: it is expected that each test procedure will take approximately (2) hours to implement. Time required to make modifications or correct deficiencies found during the test will be in addition to this allowance.
- F. The Commissioning Authority shall schedule and administer the testing once all construction checklists have been completed by the contractors and accepted by the Commissioning Authority.

## 1.2 DOCUMENTATION, NON-CONFORMANCE AND APPROVAL OF TESTS

- A. Documentation.
  - 1. The Commissioning Authority shall witness and document the results of all functional performance tests using the specific procedural forms developed for that purpose. Prior to testing, these forms are provided to the Owner's Representative for review and approval and to the Subs for review. The Commissioning Authority will include the filled out forms in the O&M manuals.
- B. Non-Conformance.
  - 1. The Commissioning Authority will record the results of the functional test on the procedure or test form. All deficiencies or non-conformance issues shall be noted and reported to the Owner's Representative on a standard non-compliance form.
  - 2. Corrections of minor deficiencies identified may be made during the tests at the discretion of the Commissioning Authority. In such cases the deficiency and resolution will be documented on the procedure form.
  - 3. Every effort will be made to expedite the testing process and minimize unnecessary delays, while not compromising the integrity of the procedures. As tests progress and a deficiency is identified, the Commissioning Authority discusses the issue with the executing contractor.
  - 4. When there is no dispute on the deficiency and the Contractor accepts responsibility to correct it:
    - a) The Commissioning Authority documents the deficiency and the Contractor's response and intentions and they go on to another test or sequence.

- b) After the day's work, the Commissioning Authority submits the non-compliance reports to the Owner's Representative for signature, if required. A copy is provided to the Contractor and Commissioning Authority.
- c) The Contractor corrects the deficiency, signs the statement of correction at the bottom of the non-compliance form certifying that the equipment is ready to be re-tested and sends it back to the Commissioning Authority.
- d) The Commissioning Authority reschedules the test and the test is repeated.

## **01662 – COMMISSIONING PROCESS REQUIREMENTS**

- A. Other Sections
  - 1. 01312 – Project meetings
  - 2. 01334 – Shop drawings, product data, and samples
  - 3. 01660 – System & Equipment Startup & Testing
  - 4. 01664 – Training
  - 5. 01830 – Operating and maintenance
  - 6. 15950 – Testing, adjusting, & balancing

### **PART 2 – GENERAL**

#### **1.1 SECTION INCLUDES**

- A. Definitions
- B. Summary
- C. Contractor Involvement
- D. General Information
- E. Included Systems
- F. Commissioning Team
- G. Construction Checklists
- H. Site Observation and Verification

#### **1.2 DEFINITIONS**

- A. A/E: Architect / Engineer.
- B. CM: Construction Manager
- C. CxA: Commissioning Authority
- D. GC: General Contractor
- E. O&M: Operations and Maintenance Information
- F. P/T: Pressure / Temperature
- G. TAB: Test, Adjust and Balance

#### **1.3 SUMMARY**

- A. The Commissioning Authority is a reviewing entity employed directly by the Owner to verify that the Owner's Project Intent is met, and to assist the Owner by providing Quality Improvement.
- B. Site Observation and Verification.
  - 1. The Commissioning Authority site observation reports may include construction issues, access and maintenance issues, safety issues, or other issues. Each observation is intended to improve the project quality and achieve the Owner's Project Intent.
  - 2. The Commissioning Authority site observation reports are not "punch lists" in that they focus on systemic problems. Where an issue is identified, not all of the same components will have been verified by the Commissioning Authority.

#### **1.4 CONTRACTOR INVOLVEMENT.**

- A. GENERAL

1. The contractors will be required to perform certain tasks, to assist in the commissioning process. These are described in this specification. Sample documents are available upon request.
2. The responsibility for the construction quality rests with the contractors.
3. The Commissioning Authority has no authority to change the contract or direct the contractor in any of their work, only to provide comments and suggestions. Issues that cannot be resolved between the contractor and Commissioning Authority will be jointly presented to the Owner for resolution.
4. Pursuant to each Commissioning Authority field comment, the Contractor will consider the comment and form a response. Responses shall be returned to the Commissioning Authority in a timely fashion, for proper feedback and to facilitate subsequent review and resolution.

**B. GENERAL CONTRACTOR**

1. The Commissioning Authority activities will be keyed to the construction activities, and so it is essential that the construction scheduling be actively communicated to the Commissioning Authority. To this end, the GC shall be responsible to communicate to the Commissioning Authority the construction schedules, milestones, completion schedules, planned testing, etc., including updates, in the same fashion, timeliness and level of detail as is provided to the Owner. The Commissioning Authority may or may not attend every construction meeting, and so relying on the dissemination of this information entirely as part of the normal construction meetings is not acceptable.
2. The GC shall be responsible to make sure that accurate record drawings are maintained by each trade, at the job site, throughout the construction phase. The record drawings shall be available for review by the Commissioning Authority at any time during normal business hours. If discrepancies are noted on the contractor's record drawings, these shall be corrected promptly to maintain the accuracy of the record drawings throughout the project.
3. The GC shall be responsible to make sure that each subcontractor cooperates and provides information, assistance, and responses to the Commissioning Authority as described, and within the time frame described.
4. **Warranty.**
  - a) The GC will provide a summary of all warranty items. The items will be delineated by specification section number, title, and description.

**C. EQUIPMENT SUPPLIERS**

1. Provide to the contractor all requested submittal data and O&M data, as described in section 3 of this specification.

**D. DIVISION 15 CONTRACTOR.**

1. Construction and Acceptance Phase
  - a) The contractor will be responsible to provide submittal data, commissioning documentation, O&M data and training required by this Commissioning Specification, including information from equipment suppliers.
  - b) Attend meetings necessary to facilitate the Commissioning process (refer to section 3 of this specification for more information on meetings).
  - c) Complete construction checklists provided by Commissioning Authority and return completed forms for scanning.
  - d) Provide to Commissioning Authority all requested submittal data and O&M data, as described in section 3 of this specification.

- e) Address current A/E punch list items before functional testing. Air and water TAB shall be completed with discrepancies and problems remedied before functional testing of the respective air- or water-related systems.
  - f) Correct deficiencies (differences between specified and observed performance) as interpreted by the Commissioning Authority, Owner, and A/E and retest the equipment.
  - g) Provide training of the Owner's operating staff, as described in section 3 of this specification
  - h) Install a P/T plug at each water sensor which is an input point to the control system.
  - i) Assist and cooperate with the Commissioning Authority. Provide skilled technicians familiar with this building to assist the TAB Contractor, execute the functional testing of the control system, and perform functional testing of equipment.
2. Warranty Period
- a) Execute seasonal or deferred functional performance testing, witnessed by the Commissioning Authority. Correct deficiencies and make necessary adjustments to O&M manuals and record drawings for applicable issues identified in any seasonal testing.
- E. CONTROLS CONTRACTOR
1. Construction and Acceptance Phase.
- a) The contractor will be responsible to provide submittal data, commissioning documentation, O&M data and training required by this Commissioning Specification, including information from equipment suppliers.
  - b) Attend meetings necessary to facilitate the Commissioning process (refer to section 3 of this specification for more information on meetings).
  - c) Complete construction checklists provided by Commissioning Authority and return completed forms for scanning.
  - d) Provide to Commissioning Authority all requested submittal data and O&M data, as described in section 3 of this specification.
  - e) Correct deficiencies (differences between specified and observed performance) as interpreted by the Commissioning Authority, Owner, and A/E and retest the equipment.
  - f) Provide training of the Owner's operating staff, as described in section 3 of this specification
  - g) Assist and cooperate with the Commissioning Authority. Provide skilled technicians to execute the functional testing of the control system.
  - h) Perform functional testing as described in section 3 of this specification.
2. Warranty Period
- a) Execute seasonal or deferred functional performance testing, witnessed by the Commissioning Authority. Correct deficiencies and make necessary adjustments, including adjustments to record drawings.
- F. TEST, ADJUST AND BALANCE CONTRACTOR.
1. Construction and Acceptance Phase.
- a) Assist and cooperate with the Commissioning Authority.
  - b) Perform TAB work as described in section 3 of this specification.
2. Warranty Period
- a) Execute seasonal or deferred functional performance testing, witnessed by the Commissioning Authority. Correct deficiencies and make necessary adjustments.

- G. DIVISION 16 CONTRACTOR.
1. Construction and Acceptance Phase
    - a) The contractor will be responsible to provide submittal data, commissioning documentation, O&M data and training required by this Commissioning Specification, including information from equipment suppliers.
    - b) Attend meetings necessary to facilitate the Commissioning process (refer to section 3 of this specification for more information on meetings).
    - c) Complete construction checklists provided by Commissioning Authority and return completed forms for scanning.
    - d) Provide to Commissioning Authority all requested submittal data and O&M data, as described in section 3 of this specification.
    - e) Address current A/E punch list items before functional testing.
    - f) Correct deficiencies (differences between specified and observed performance) as interpreted by the Commissioning Authority, Owner, and A/E and retest the equipment.
    - g) Provide training of the Owner's operating staff, as described in section 3 of this specification
    - h) Assist and cooperate with the Commissioning Authority. Provide skilled technicians familiar with this building to perform functional testing of equipment.
  2. Warranty Period
    - a) Correct deficiencies and make necessary adjustments to O&M manuals and record drawings for applicable issues identified in any seasonal testing.

#### 1.5 GENERAL INFORMATION

- A. Sampling:
1. Generally, representative samples of the work will be periodically verified by the Commissioning Authority to be used as an indicator of the quality of the work. For example, if there are 100 VAV boxes, 10% of them may be randomly checked during a site visit for proper installation, and a different 10% of them may be verified for proper control sequence during a later site visit. If the sampled units appear to be installed and working properly, the remaining VAV boxes would be presumed acceptable. If consistent problems are found with the VAV boxes sampled, then the contractor is responsible for inspecting and correcting the problem on all of the VAV boxes. This would then be followed by another random verification by the Commissioning Authority.
  2. This sampling method will be used as a quality check for equipment, ductwork, record drawings, etc. Where repetitive work is involved, the intent will be that Commissioning verifications occur when the work first begins and throughout construction, so that any resulting changes affect only a small portion of the repetitive work and not all of it. This method has the effect correcting problems early, while they are still relatively easy to correct. In this way the Commissioning Authority is a benefit to the contractor, by reducing costly re-work and schedule delays, especially where repetitive tasks are concerned.
- B. Problem Solving.
1. The Commissioning Authority will recommend solutions to problems found, however the burden of responsibility to solve, correct and retest problems rests with the Contractors and the A/E.
- C. Communication during Construction Phase.

1. **EDIT** Comments, observations, etc. from the Commissioning work will be relayed directly to the responsible party whenever possible, with copies to the Owner, AE and GC. This includes submittal comments, site observation reports, test reports, etc. The direct communication approach will avoid delays from traditional remote paper exchanges, will encourage dialogue and discussion of options and alternatives, and generally maintain an atmosphere of cooperation and quality.
- D. Response Times.
1. Timeliness in delivering information or forming responses to the Commissioning Authority, and back, are essential to providing the construction product to the Owner on time, as well as the commissioning quality control implementation process. The following are guidelines established to meet this objective, and should be followed unless there are extenuating circumstances – in which case the delay shall be explained to each party in advance of the delay.
  2. Delivery of construction checklist book by Commissioning Authority to GC: 10 days before delivery of commissioned equipment.
  3. Submittal review by Commissioning Authority:
    - a) 3 days
  4. Delivery of O&M manuals to Commissioning Authority:
    - a) 90 days after approved submittals.
  5. Delivery of Final Record Drawings to Commissioning Authority:
    - a) 2 weeks prior to Owner training required by contract documents.
  6. Delivery of Training Material to Commissioning Authority:
    - a) 60 days prior to the scheduled training.
  7. Delivery of detailed control logic diagrams to Commissioning Authority:
    - a) 30 days after approved submittals.
  8. Delivery of Control Software to Commissioning Authority:
    - a) 60 days after approved submittals.
  9. Proof of TAB contractor's proof of successful completion of a project of this size and complexity, to Commissioning Authority:
    - a) 7 days prior to bid opening,
  10. Deliver TAB test plan to Commissioning Authority:
    - a) 60 days after contract award.
  11. Response by contractor to Commissioning Authority field comment:
    - a) 2 weeks or less from receipt of comment.
  12. Delivery of testing procedures by Commissioning Authority to GC:
    - a) 1 month prior to testing.
  13. Time to correct discrepancies noted in Record Drawings during construction phase:
    - a) 2 weeks from the date the discrepancy was noted.
- E. Warranty
1. The GC shall provide a summary of warranty items specified as part of their design. The items will be delineated by specification section number, title, and description, to facilitate a double check and comparison of the summary of warranty items prepared by the A/E. This step is intended to assure the Owner that the intended warranty protection will be provided to the Owner.
  2. For each warranted item, include the date when the warranty is to begin, the duration of the warranty, and Owner's obligations to maintain warranty.
- F. Warranty Review.
1. Prior to the end of the contractor's guarantee period, the Commissioning Authority will review operational issues reported by the maintenance personnel, to help determine if the operational problems have

construction defects as their root cause. Then, the Commissioning Authority will work with the contractor to correct the defects.

#### 1.6 INCLUDED SYSTEMS **EDIT LIST**

- A. The GC shall establish a contact person for each trade or system involved in the commissioning process, as listed below. This requirement is intended to facilitate effective communication during the commissioning process. There may be more than one person, and there may be alternate contact persons, as may be appropriate.
- B. The following systems and their components are included in the scope of the Commissioning activities, and so will require involvement from the associated contractors:
- C. Division 1-14
  - 1. Building Envelope (insulation, glazing, etc.).
  - 2. Transport Systems
- D. Division 15 – Mechanical
  - 1. Chillers
  - 2. Cooling Towers
  - 3. Boilers
  - 4. Pumps
  - 5. Fans
  - 6. Air handling units, including terminal devices
  - 7. Ductwork
  - 8. Piping
  - 9. HVAC control system
  - 10. Testing, adjusting and balancing
  - 11. Natural ventilation systems
- E. Division 16 – Electrical
  - 1. Daylighting systems
  - 2. Emergency power systems
  - 3. Fire alarm system

### PART 3- PRODUCTS

- 1.1 None

### PART 4 - EXECUTION

#### 1.1 COMMISSIONING TEAM

- A. Each contractor shall designate a single individual to be responsible for coordinating commissioning activities with the Commissioning Authority.
- B. The members of the commissioning team consist of the Owner, Commissioning Authority (CxA), **EDIT** the Construction Manager (CM), O&M personnel, General Contractor (GC), the Architect and Design Engineers (A/E), the Mechanical Contractor, the Electrical Contractor, the Test Adjust and Balance Contractor (TAB), and the Controls Contractor.

#### 1.2 CONSTRUCTION CHECKLIST

- A. The intent of the construction checklist is to provide a formalized means to easily track construction progress and to provide individual workers the key criteria for a successful installation.
  - 1. Delivery and Construction checklists are described in detail below. These are equipment-specific and will be barcode tracked.

2. System checklists (for piping, ductwork, cable trays, etc.) are different from the Delivery and Installation checklists described below. They do not have bar codes associated with them. Although they are not formally tracked, they will be used by the Commissioning Authority during periodic site observations. The System checklist items are reminders to the contractors of some common items that have been problematic on other projects.
- B. Construction checklists for all pieces of equipment typically follow the same format, yet are tailored to the specific equipment being installed.
  - C. Construction checklists are developed for each individual piece of equipment or system (e.g. ductwork) to track and verify equipment from when they are delivered, installed and started up. The contractor will be provided with all checklists developed for each piece of equipment or system and the following:
    1. Instructions and Checklist Procedures.
    2. Bar coded checklists with the following sections:
      - a) Pre-Installation Checks: Includes several yes/no or short answer questions to document the condition of the equipment prior to installation and several blank columns to compare delivery items such as manufacturer, model, serial no., etc. to the corresponding submitted/approved items.
      - b) Installation and Startup: Includes several yes/no or short answer questions to document that the equipment is installed, electrically wired, controlled and started up and balanced according to the specified requirements. A Negative Responses section is included at the end of the checklist to document the reasons for any "no" responses or discrepancies in the various sections. A space is included to document the actions taken to correct the problems resulting in "no" responses.
  - D. The construction checklists shall be distributed by the supervisor to individual workers (teams) at the start of each day for the equipment or system to be installed or worked on that day.
  - E. The checklist shall be completed by the individual actually completing the work. Prior to any work, the checklist shall be reviewed by the individual contractor for pertinent information. Any negative responses on the checklist shall be explained and documented at the end of the checklist. The Commissioning Authority will review each checklist with the respective contractor(s) prior to the installation of the first component of an item (e.g., the first unit heater) to ensure they understand the use of the checklist.
  - F. All Installation Checklists shall be returned to the supervisor upon completion of the work at the end of each day and scanned in to the electronic database provided by the Commissioning Authority. Scanning reports from this electronic database can be made available to the General Contractor and subcontractors electronically or on-line through the World Wide Web at the discretion of the Owner.
    1. **EDIT** Scanner and software for scanning provided by Commissioning Authority.
  - G. The checklists cannot be filled out by a supervisor or other individual who did not work on the equipment.
  - H. The completion of the checklist does not eliminate the contractor's responsibility for meeting other requirements in the specifications and drawings.
  - I. The Commissioning Authority will periodically (daily/weekly) verify the accuracy, completeness and tracking of the checklists. If consistent errors are found, the responsible contractor shall re-validate 100% of the checklists for the problem equipment or system type.
  - J. The use of Checklists are not intended to increase the work of the contractors, but to detect and eliminate delivery, installation and startup problems, and

problems with miscommunication. This process also serves as a convenient way to document the progress of the work.

### 1.3 SITE OBSERVATIONS AND VERIFICATIONS.

- A. The Commissioning Authority will periodically visit the site to observe the work in progress. Observations and recommended corrective measures will be communicated to the contractor and Owner.
- B. The field observation reports may include construction issues, access and maintenance issues, or other issues. Each observation is intended to improve the project quality and achieve the Owner's Project Intent. It is important to note that the Commissioning reports are not "punch lists". At the Owner's discretion, the field observation lists may be delivered to the General Contractor directly, or incorporated to or added to the A/E's and/or the Owner's reports.

## 01664 – TRAINING

[Insert the following in 01664]

### 1.1 TRAINING

#### A. General.

1. The Commissioning Authority will review the proposed training material from the individual contractors.
2. The Commissioning Authority will provide comments to supplement training material for operations and maintenance personnel, where appropriate.
3. The Commissioning Authority will provide a coordinated training product through supervision.
4. The Commissioning Authority will compile electronic copies of training material for the Owner's use and reference. Paper copies will be in 3-ring binders. Electronic copies will be on CD-ROM media, in a format that is searchable and printable, such as Adobe Portable Document Format (PDF).
5. The contractor for the respective system is responsible for the development and implementation of the training material for the system.
6. Training materials and O&M manuals must be submitted to and accepted by the Commissioning Authority and accepted prior to commencement of any training.
7. Format for contractor-submitted training material:
  - a) Detailed agenda
  - b) Contractor contact sheet, including address, phone number, fax number and e-mail.
  - c) Detailed training material, divided by sections.
  - d) Maintenance checklists/ log sheets.
8. At the Owner's option, training may be videotaped for future reference and training.
9. All training sessions shall be scheduled and coordinated by the General Contractor through the Owner's Representative.
10. Training shall be completed and accepted by the owner prior to substantial completion and occupancy.
11. Supplemental training after building occupancy:
  - a) It is intended that one or two supplemental training sessions occur after building occupancy, primarily for the controls system, for the benefit of the O&M staff.

#### B. Minimum Allowances for Training Time **EDIT**

1. Unless Div. 1, Div. 15, or Div. 16 requirements are more strict, provide the following as a minimum:
2. Div. 15 – Mechanical:
  - a) Mechanical Systems, air side, water side, equipment: 40 hours
  - b) Temperature Controls: 40 hours
3. Div. 16 – Electrical:
  - a) Daylighting systems 8 hours
  - b) Electrical Systems, normal power, emergency power, lighting, equipment: 24 hours
  - c) Specialty - Fire Alarm: 24 hours

#### C. Responsibilities Of Other Parties.

1. A/E

- a) Provide an introductory segment of Owner training to explain the Basis of Design, to familiarize the O&M staff with the design aspects of the building.
- 2. General Contractor
  - a) The GC shall be responsible for training coordination and scheduling and ultimately to ensure that training is completed.
- 3. Mechanical Contractor
  - a) Provide the Commissioning Authority with a training plan two weeks before the planned training. Manuals must be approved by the Commissioning Authority prior to commencing with training.
  - b) The training topics shall include all of the mechanical equipment and systems. The mechanical contractor shall provide training on each piece of equipment. Training syllabus shall include a breakdown of the time allotted for each system.
  - c) Provide designated Owner personnel with comprehensive orientation and training in the understanding of the systems and the operation and maintenance of each piece of HVAC equipment including, but not limited to, pumps, boilers, furnaces, chillers, heat rejection equipment, air conditioning units, air handling units, fans, terminal units, controls and water treatment systems, etc.
  - d) Training shall normally start with classroom sessions followed by hands-on training on each piece of equipment, which shall illustrate the various modes of operation, including startup, shutdown, fire/smoke alarm, power failure, etc.
  - e) Training topics shall include safe and proper operating requirements, preventative maintenance, special tools needed, recommended spare parts, common troubleshooting problems and solutions, and any equipment or system peculiarities. The training shall include start-up, operation in all modes possible, shut-down, seasonal changeover and any emergency procedures.
  - f) Hands-on training shall include start-up, operation in all modes possible, including manual, shut-down and any emergency procedures and preventative maintenance for all pieces of equipment.
- 4. Controls Contractor.
  - a) The controls contractor shall have the following training responsibilities:
  - b) Provide the Commissioning Authority with a training plan four weeks before the planned training. Manuals must be approved by the Commissioning Authority prior to commencing with training.
  - c) There shall be three training sessions:
  - d) The first training shall convey the basic system layout and functionality, introduce the basic hardware items, software features, location of documents, special terms, etc. Upon completion, each student, using appropriate documentation, should be able to perform elementary operations and describe general physical layout of the system, and procedures for obtaining vendor assistance. This training session may be held on-site or off-site, as appropriate.
  - e) The second session shall consist of actual hands-on training. The session shall include specific instruction for operating the installed system, including any interface with other systems such

as lighting and Fire Alarm. Software features shall be explained including security levels, alarms, system start-up and shutdown, power fail restart routines, changing setpoints, acknowledging alarms, overrides, manual operation of equipment, etc. Trainees shall set up and print out trends and reports using actual system data. Trainees shall set up a graphic display using actual system data.

- f) The third training will be conducted on-site six months after occupancy and will be structured to address specific topics that trainees need to discuss and to answer questions concerning operation of the system.

D. Training Agendas

1. Prepared training agenda forms shall be partially filled out by the Commissioning Authority and the owner and submitted to the relevant contractors. Contractors shall be instructed to complete certain sections and re-submit to the Commissioning Authority for approval. Upon approval, the contractor may then provide copies of the approved training agenda to the trainers and trainees. The agenda shall be followed to assure efficient training and a knowledge level that meets or exceeds the owner's intent.
2. The trainer, prior to and during each training session, shall complete the prepared training record form. The trainer is responsible for checking the subjects covered from the training agenda and for obtaining signatures from the trainees in attendance.

## Appendix K: Site Visit Procedure

Having a consistent site visit procedure is a critical aspect of ensuring the commissioning process is being properly integrated into the construction of a building. The procedure to be followed during all site visits is detailed in this document. These steps will be in addition to any items that require specific attention or which are the primary purpose of the visit (training, equipment start-up, etc.). The procedure is:

1. Prior to the first site visit, divide the floor plan drawings into an equal area grid. The grid density is typically 6 by 5. For smaller drawings, the grid density is often reduced to 5 by 3. The grid density is set to obtain a good sampling of the various systems in the building. The density is typically too coarse if an entire system (central and distribution) is contained in a single grid. Conversely, the density is too fine if only a single component is consistently in a grid (VAV box, etc.).

Concurrent to the grid layout, the sampling frequency should be determined. The sampling frequency randomly selects every  $x^{\text{th}}$  square on the floor plans to be verified. Squares that are completely blank (no walls, equipment, etc.) are not included in the counting. The sampling is started in one of the 1<sup>st</sup> six squares, randomly selected using a die. The frequency is determined in concert with the grid density so that between 5% and 20% of the floor space is verified every visit. The actual percent floor space to be verified is based on the size of the project. Typically, the larger the project, the lower the percent floor space checked.

It is recommended that a separate set of drawings be marked with the grid and blank grids x'd out. This will simplify the selection and verification of the system during site visits.

2. Document the procedure to be used:
  - (1) The grid density is \_\_\_\_\_ by \_\_\_\_\_ for each drawing.
  - (2) The sampling frequency is every \_\_\_\_\_ grid.
  - (3) Eliminating blank grids, this results in checking \_\_\_\_\_ % of the floor space.
3. A log shall be kept (see attached) of the date of each site visit and the starting grid number.
4. For each site visit the following procedure shall be used:
  - a. Prior to leaving for the site visit, determine the starting grid number using a random selection process (die, 1-6 in a hat, etc.).
  - b. Review the selected grids and identify the equipment to be verified. Review past problems with commissioning efforts on this equipment (see site visit log).
  - c. Review the design intent.
  - d. On-site, for each selected grid, verify:
    - i. As-built drawings are accurate (location of equipment, room numbers, equipment sizes, etc.).
    - ii. Accessibility to equipment and components for maintenance is good (controls, electrical disconnects, junction boxes, valves, filters, coils, etc.).
    - iii. Verification checklists are up-to-date and accurate (initial off what was checked on the verification checklist).
  - e. Meet with individual primary commissioning team members to determine state of construction, coordination problems, commissioning questions, and discuss any commissioning or quality problems found during the site visit.
  - f. Complete Site Visit Report (see attached).
  - g. For each commissioning issue identified during the site visit, add an entry into the commissioning issues database for the project.

5. After each site visit, review the site visit procedure and forms and modify as required to improve the process. Also, document and implement, as appropriate, input from other commissioning team members.
6. At the end of each project, meet with the commissioning team members to obtain feedback on how the site visit reports worked and what can be done better.

## Site Visit Log

*(Project Name/Location)*

[illegible]

**Site Visit Report**  
(Project Name/Location)

Site Visit #: \_\_\_\_\_ Date: \_\_\_\_\_ Investigator (s): \_\_\_\_\_

Drawing Page Number	Grid Start Number	Grid Sampling Frequency

As-built Drawings Verified: ☐ Yes ☐ No

Verification Checklists Verified: \_\_\_\_ Yes \_\_\_\_ No

**List Commissioning Team Members That Were Met and Summary of Discussion:**

Team Member Name	Summary of Discussion

**List Systems and Components Verified During this Site Visit, and Circle if a Problem was Found:**

1)	2)	3)	4)	5)
6)	7)	8)	9)	10)
11)	12)	13)	14)	15)
16)	17)	18)	19)	20)
21)	22)	23)	24)	25)
26)	27)	28)	29)	30)
31)	32)	33)	34)	35)

**List Problems Encountered, # from the Components Verified List, and Recommended Solution/Follow-up:**

[illegible]

## Appendix L: Example Construction Checklist

This Construction Checklist is for a typical constant or variable air volume terminal unit. Space for negative responses would typically be added to the end of the checklist.

A. Delivery:		Submitted	Delivered
1	Inspect components for obvious damage		
2	Manufacturer		
3	Model number		
4	Serial number		
5	Rating, size		
6	Inlet size		
7	Minimum airflow		
8	Maximum airflow		
9	Motor, V/A/phase		
10	Constant volume / Variable volume		
11	Controller		
B. Physical Verification:		Verification	Initial
1	Free of damage	Y / N	
2	Seismic bracing	Y / N	
3	The airflow sensing tubing is plugged	Y / N	
4	The grommets for the airflow sensing tubing are secure	Y / N	
5	The enclosure for the DDC control panel is in the proper location	Y / N	
6	Unit tags affixed	Y / N	
7	Mfg.'s rating readable/accurate	Y / N	
C. Installation:			
1	Unit		
a.	Seismically braced	Y / N	
b.	Metal to metal connections eliminated to prevent noise problems	Y / N	
c.	Adequate clearance around control panel for maintenance	Y / N	
d.	Clear access below terminal unit for easy maintenance	Y / N	
2	Ductwork.		
a.	Balancing damper present on inlet	Y / N	
b.	Straight duct 1.5 times duct diameter upstream of air valve	Y / N	
c.	Downstream ductwork free of transitions for at least 36"	Y / N	
d.	Maintainable items easy to access	Y / N	
e.	Flexible connector installed on inlet duct	Y / N	
f.	Flex duct (if used) installed in such a way that kinks are avoided	Y / N	
3	Motor and controller		
a.	Motor vibration isolation	Y / N	
b.	Labeling of wiring	Y / N	
c.	Tight connections	Y / N	
d.	Control wiring installation	Y / N	
e.	Record drawings updated	Y / N	
4	Temperature sensor calibration verified	Y / N	
5	Airflow sensor calibration verified	Y / N	
6	Point-to-point connections of control wiring verified	Y / N	
7	Central system accurately represents conditions of air valve	Y / N	
D. Start-Up:			
1	Motor and controller operational	Y / N	
2	Control and signal response sequence	Y / N	

## Appendix M: Qualification Based Commissioning Authority Selection

### Commissioning Authority Services Request for Qualifications

#### **BACKGROUND**

\_\_\_\_\_ (Owner) is seeking the services of a qualified Commissioning Authority/firm for a new school construction project. The project is a \_\_\_\_\_ gross square foot, \_\_\_\_-story, Class \_\_\_\_ [type] school building in \_\_\_\_\_, California, with a project budget of \$\_\_\_\_\_ million.

The project is in the early pre-design (programming) phase. The tentative schedule for the project is:

- Complete pre-design: [insert date]
- Schematic design: [insert date]
- Design development: [insert date]
- Draft construction drawings: [insert date]
- Final construction drawings: [insert date]
- Construction start: [insert date]
- Construction end: [insert date]
- Occupancy/warranty start: [insert date]
- Seasonal testing: [insert date]
- Lessons learned meeting: [insert date]
- Commissioning Process final report [insert date]

**Modify the previous to indicate projects where the Commissioning Authority is contracted with after the pre-design phase.**

The management structure is traditional “design / bid / build” with full design documents and specifications to be developed by an architectural firm. The construction documents will be let out to bid and a general contractor will be hired to complete the construction. The design team will have limited construction oversight. The Owner’s primary construction representative on-site will be provided by the separately contracted services of a construction management firm. The Commissioning Authority will report to the Owner.

**If the project is not a design / bid / build, describe the structure and the oversight and lines of responsibility for the A/E, Commissioning Authority and Owner’s representative.**

#### **SCOPE OF WORK**

The Owner has adopted the quality-based Commissioning Process as their means to oversee the planning, designing, construction and operation of this school. As with any quality-based process, the Commissioning Process provides tools to enable everyone involved to achieve a final building meets the original intent of the Owner.

For specifics on the level of effort required for the individual Commissioning Authority responsibilities, refer to ASHRAE/NIBS Guideline 0 (latest version). The following are the Commissioning Process activities that the Owner intends to have implemented on this project. The proposer is free to suggest changes and improvements to this process. However, for this proposal the following process will be assumed.

### **Commissioning Process Activities During the Pre-Design Phase**

The key Commissioning Process activities accomplished by the Commissioning Authority during the Pre-Design Phase are:

1. Facilitates the development of the Project Intent document through the convening of a Nominal Group Technique workshop.
2. Develops a Commissioning Plan encompassing the activities completed in support of the Commissioning Process by all project stakeholders during the planning (pre-design), design, construction, and operation phases. The Commissioning Plan shall be organized and formatted to become the final report at project completion.
3. Implement an electronic database for the tracking and resolution of Commissioning Process issues, including documentation of the estimated costs and savings of identifying and resolving each issue earlier in the project than it would have been without the Commissioning Process.
4. Develop Commissioning Process progress reports including a summary of the issues identified and resolved along with the estimated savings.

### **Commissioning Process Activities During the Design Phase**

The key Commissioning Process activities accomplished by the Commissioning Authority during the Design Phase are:

1. Provide the design team with guidance on compiling and documenting the Basis of Design for the project.
2. Develop draft Construction Checklists.
3. Facilitate a training requirements workshop with the Owner's operation and maintenance staff to define and document the level and type of training required.
4. Provide the design team with changes to the project specifications to integrate the Owner's requirements in support of implementing the Commissioning Process.
5. Perform statistically-based (sampling) design review for the design submissions (schematic design, design development, and draft and final construction documents).
6. Modify the Project Intent to document changes and decisions made.
7. Maintain the issues database.

### **Commissioning Process During the Construction Phase**

The key Commissioning Process activities accomplished by the Commissioning Authority during the Construction Phase are:

1. Facilitate discussion during the pre-bid and pre-construction meetings on the contractor Commissioning Process activities, the Project Intent, and the Basis of Design.
2. Organize and direct Commissioning Team meetings to plan Commissioning Process activities, clarify scope, identify and resolve coordination issues, schedule future activities, and resolve Commissioning Process issues.
3. Review selective sampling of contractor submittals to verify Project Intent is being achieved. Provide comments to the design team for inclusion with their response.

4. Review draft Construction Checklists with the contractors.
5. Provide final Construction Checklists to the contractors for their completion. Train the contractors on completing the Construction Checklists and subsequent processing of the collected information.
6. Accomplish periodic site visits to verify achievement of the Project Intent by the contractor. Use quality-based sampling techniques on the record drawings, completed Construction Checklists, and contractor tests to accomplish this verification.
7. Update the Project Intent and Commissioning Plan, and verify changes to the Basis of Design.
8. Organize and direct Commissioning Team meetings to plan Commissioning Process activities, clarify scope, identify and resolve coordination issues, schedule future activities, and resolve Commissioning Process issues.
9. Develop test procedures for the verification of the Project Intent prior to occupancy.
10. Review training plans, materials, coordination, and sessions for achievement of the Project Intent.
11. Witness selected performance and start-up tests performed by the contractor.
12. Verify compilation of the Systems Manual.
13. Oversee and document the completion of Commissioning Process tests by the contractors.
14. Maintain the issues database.

#### **Commissioning Process During the Occupancy and Operations Phase**

The key Commissioning Process activities accomplished by the Commissioning Authority during the Operations and Occupancy Phase are:

1. Update Project Intent and Basis of Design.
2. Accomplish bi-monthly site visits to verify on-going achievement of the Project Intent, to prepare for seasonal testing, to aid in resolving outstanding issues, and to verify upkeep of the Systems Manual.
3. Oversee and document the completion of seasonal testing performed by the Owner's operation and maintenance staff.
4. Coordinate additional training.
5. Accomplish a warranty walk-through at the 10-month point of warranties with the operations and maintenance staff.
6. Participate in a Lessons Learned workshop, facilitated by an independent member of the Commissioning Authority firm.
7. Develop and distribute Commissioning Process Final Report.

The Commissioning Authority is not responsible for design concept, design criteria, compliance with codes, design or general construction scheduling, cost estimating, or construction management. The Commissioning Authority may assist with problem-solving or resolving non-conformance or deficiencies, but ultimately that responsibility resides with the general contractor and the designers of record.

### **Focus of the Commissioning Process**

The following assemblies, components, systems and equipment are the focus of the Commissioning Process due to their complexity and importance in the final building:

<b>Delete and add systems as desired.</b>
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1. Building envelope
2. Landscaping
3. Central building automation systems
4. Heating, ventilating and air-conditioning systems
5. Refrigeration systems
6. Life safety systems (fire alarm, egress pressurization, fire protection)
7. Domestic and process water pumping systems
8. Emergency power and uninterruptible power supply (UPS) systems
9. Lighting (including daylighting) control systems
10. Communication and paging systems
11. Other Collaborative for High Performance Schools (CHPS) requirements

## **DESIRED QUALIFICATIONS**

It is desired that the person designated as the Commissioning Authority satisfy as many of the following requirements as possible:

1. Have acted as the principal Commissioning Authority for at least three projects during the past three years.
2. Have extensive experience with the requirements and applications of the CHPS Rating System.
3. Experienced in quality processes and statistical sampling.
4. Excellent verbal and writing communication skills. Highly organized and able to work with both management and trade contractors.
5. Have extensive experience in the planning, design, construction, and operations of school facilities. Extensive field experience is required. A minimum of five full years in this type of work is required.
6. Knowledgeable in building operation and maintenance training.
7. Knowledgeable in test and balance of both air and water systems.
8. Experienced in energy-efficient equipment design and control strategy optimization.
9. Direct experience in monitoring and analyzing system operation using energy management control system trending and stand-alone datalogging equipment.
10. Technical experience in the school construction industry. This could be a degree in building sciences (mechanical engineer, electrical engineer, architect, etc.) or certification (P.E., RA, CxAP, etc.), with appropriate experience is desirable. Other technical training and past Commissioning Process and field experience will be considered.

The Commissioning Authority's firm will demonstrate depth of experienced personnel and capability to sustain loss of assigned personnel without compromising quality and timeliness of performance.

The Commissioning Authority will be an independent contractor and not an employee or subcontractor of the General Contractor or any other subcontractor on this project, including the design professionals.

## **INSTRUCTIONS TO PROPOSERS**

A proposer must propose to execute all phases of the Commissioning Process in a single proposal.

The proposal must be signed by an officer of your firm with the authority to commit the firm.

The proposal shall be limited to 20 single-sided pages, including graphics. A letter of introduction, section dividers, detailed resumes and the sample work products of item five below are not included in this limit.

1. List the key individual who will be the Commissioning Authority for this contract and describe his or her relevant qualifications and experience (including if certified by the University of Wisconsin or the Building Commissioning Association). This information is required in addition to any detailed resumes the proposer submits. The contract will require that this individual be committed to the project for its duration.
2. Provide a summary of past relevant projects that clearly documents the value the Commissioning Process brought to the project and to the Owner's long-term process changes. Include a minimum of three projects with a description of the project, when you came into the project, and describe the general scope of work. Provide additional detailed information for each project in the attached Commissioning Process Project Experience Listing form (Exhibit 2).

3. Describe any experience of the proposer's team in the following areas. List each party's involvement.

- a. Quality process experience
- b. Operations and maintenance experience
- c. Facility optimization experience (envelope, mechanical, and lighting systems)
- d. Energy-efficient equipment design and control strategy optimization
- e. Life cycle costing
- f. Experience in environmental sustainable design
- g. Project and construction management

4. Describe your proposed approach to managing the project expertly and efficiently, including your team participation. Describe what approach you will take to integrate the Commissioning Process into the normal planning, design, construction, and operation process in order to make it "business as usual".

Describe what you will do to foster teamwork and cooperation from contractors and designers and what you will do to minimize adversarial relationships. Describe how your work will facilitate the adoption of the Commissioning Process for use by the Owner in future projects, including access to the electronic versions of all documents and forms.

5. As an attachment, provide the following work products that members of the proposer's team wrote.

- a. Commissioning plan that was executed on a school
- b. Integration of Commissioning Process requirements into the project specifications
- c. Output report of electronic database for automatic Construction Checklist tracking

Fill out the attached Commissioning Authority Firm Experience and the Commissioning Process Project Experience Listing forms (Exhibits 1 and 2, respectively).

### **SELECTION CRITERIA**

<b>Scale the weights below as desired.</b>
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The submitted proposals will be reviewed and ranked according to the following (items from the above numbered list):

1. Commissioning Authority experience	25 points
2. Past project experience	15 points
3. Staff experience	15 points
4. Management approach	30 points
5. Work examples	<u>15 points</u>
	100 points

Reference checks will not be scored individually, but may be used to supplement all categories. The Owner reserves the right to eliminate or change the weight of all categories at any time.

### **SUBMISSION AND SELECTION**

Proposers will submit five (5) copies of the written proposal, to be received in the Owner's office at [address \_\_\_\_\_] by [date and time \_\_\_\_\_]. Late proposals will not be accepted.

All proposals will be reviewed by a panel of five (5) representing the Owner. This panel will rate and rank each respondent that has submitted a package as per the requirements of this request for qualifications.

At the discretion of the review panel, the top three (3) respondents will be asked to present their qualifications in person. The listed Commissioning Authority and key project individuals shall be present for the interview.

The review panel will enter into negotiations with the top rated respondent and request a price proposal. If the review panel and the top rated respondent cannot come to agreement on price, the review panel will progress down the ranked list until successful negotiations are reached.

### **LIMITATIONS AND PROVISIONS**

The Owner reserves the right to negotiate with a single entity, accept or reject any submission, or not award any contract from this solicitation.

The cost to prepare a response and any subsequent costs prior to signing a contract with the Owner shall be the responsibility of the individual respondents. The primary contact for questions shall be:

[insert name of contractual and technical contact]  
[title]  
[address]  
[phone]  
[fax]  
[e-mail]

### **MINIMUM REQUIREMENTS FOR CONTRACT EXECUTION**

The proposer shall review the attached sample contract and indicate any exceptions taken. If awarded the contract, it is assumed that the proposer will sign as is. Changes cannot be made unless noted in your submission.

[include typical contract requirements for the school district as a sample contract. This should include the following sections: agreement, definitions, independent contractor, disputes, control of the work, jobsite access requirements and fitness for duty, conflict of interest, documentation, insurance, dual indemnity, proprietary rights, termination and cancellation, and survival]

#### **Change in Personnel**

A change in the Commissioning Authority or key personnel must be approved by the Owner in writing before any change is made. The replacement personnel shall have, at minimum, equivalent qualifications as the original personnel.

## Exhibit 1 Commissioning Authority Firm Experience

Company Name	Contact Person	Title
Address	City	State/Prov      Zip/Postal Code
Telephone Fax	E-Mail	
Description of Business:		

Commissioning Activities:

Percentage of overall business devoted to Commissioning Process services \_\_\_\_\_%

How long has the firm offered Commissioning Process services \_\_\_\_\_ years

Average number of Commissioning Process projects performed each year: \_\_\_\_\_ projects

Systems and assemblies for which firm has provided Commissioning Process services (check all that apply):

- |   |   |   |
|---|---|---|
| <input type="checkbox"/> Pkg or split HVAC    | <input type="checkbox"/> Daylighting              | <input type="checkbox"/> Commercial refrigeration |
| <input type="checkbox"/> Chiller system       | <input type="checkbox"/> Electrical, general      | <input type="checkbox"/> Telecommunications       |
| <input type="checkbox"/> Boiler system        | <input type="checkbox"/> Electrical, emerg. power | <input type="checkbox"/> Thermal Energy Storage   |
| <input type="checkbox"/> Energy Mgmt. System  | <input type="checkbox"/> Envelope                 | <input type="checkbox"/> Labs & Clean Rooms       |
| <input type="checkbox"/> Variable Freq.Drives | <input type="checkbox"/> Fire/Life Safety         | <input type="checkbox"/> Landscaping              |
| <input type="checkbox"/> Lighting Controls    | <input type="checkbox"/> Plumbing                 | <input type="checkbox"/> _____                    |

Number of registered professional engineers and architects on staff who are Commissioning Authorities: \_\_\_\_\_

The firm has provided Commissioning Process services in the following: (check all that apply):

Building Sector	Green/Sustainable Building	New Construction Major Renovation	Existing Building (Building Tune-up)	Equipment Replacement
Elementary schools	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Grade schools	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
High schools	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Specialty schools	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Administrative facilities	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Federal, state, local gov't	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Special purpose— museums, libraries, etc.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

## Exhibit 2

### Commissioning Process Project Experience Listing

[illegible]

## References

CHPS, 2002, Volume II – Best Practices Manual, The Collaborative for High Performing Schools, San Francisco, CA.

ASHRAE, 2002, ASHRAE/NIBS Guideline 0, The Total Building Commissioning Process – Public Review, American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc., Atlanta, GA.

Delbecq, Andrew L., and Van de Ven, Andrew H. "A Group Process Model for Identification and Program Planning," *Journal of Applied Behavioral Sciences*, 1971, 7, pp. 466-492.